



**Republic of Iraq**  
**Ministry of Higher Education and**  
**Scientific Research**



**Al-Furat Al-Awsat Technical**  
**University**

**Engineering Materials**

**By:**

**Prof. Dr. Maher Hameed Majeed**

**Dr. Zainab Abdulraheem Abdulhasan**

**Polytechnic Karbala**  
**collage**

**Mechanical Engineering**  
**technical**

**First year**

**First semester**

**Academic year 2025-2026**

# **Introduction to Engineering Materials Science**

**Prof Dr. Mahir H. Majeed**

**Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Introduction to Engineering Materials Science History, Science, and Engineering

# Lecture Outline & Objectives

Key Objectives: Understanding the history of materials, defining materials science and engineering, and recognizing the importance of the field

# Why Study Materials Science and Engineering?

Importance and Impact:

Materials drive technological advancement  
(transportation, communication, energy, medicine).

# A Historical Perspective

Classical Materials Ages:

Stone Age (Natural Materials), Bronze Age (First Alloys: Copper and Tin), and Iron Age (Iron and Steel)

The Modern Materials Era:

Emergence of Polymers, Advanced Ceramics, Composites, and Nanomaterials

# What is Materials Science?

## Definition and Focus:

The study of the fundamental relationship between a material's Structure and its resulting Properties. (The scientist seeks to understand the material.)

# What is Materials Engineering?

Definition and Application:

Designing the Structure through controlled Processing to obtain specific Properties that meet required Performance.  
(The engineer seeks to apply knowledge to develop products.)

# The Essential Relationship:

- The Materials Tetrahedron | Interconnected Factors:
- Processing  $\rightarrow$  Structure  $\rightarrow$  Properties  $\rightarrow$  Performance. (Emphasize that these four components are mutually dependent)

# Key Engineering Materials Classifications

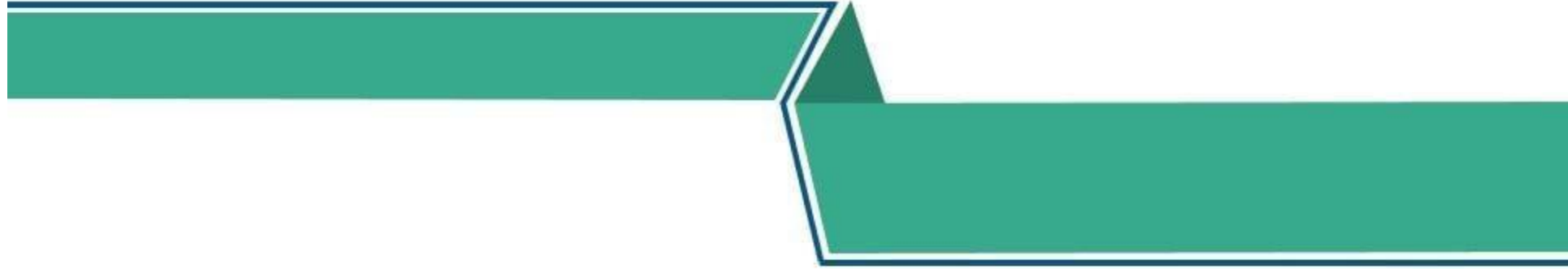
Overview of Main Families:

Metals, Ceramics, Polymers, and Composites. (Briefly mention a distinguishing characteristic for each)

# Summary and Conclusion

Reiterate the field's importance, the historical context, and position Materials Science and Engineering as the bridge between fundamental sciences and application engineering

“Thank You”



# **Main Content Focus**

**Prof Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Materials Classification Details

**Metals:** Metallic bonding, high conductivity, ductility.

**Ceramics:** Ionic/Covalent bonding, high hardness/brittleness, low conductivity

**Polymers:** Covalent/Secondary bonding, large molecular chains, low density, flexibility.

**Composites:** Combination of two or more families (e.g., Fiberglass).

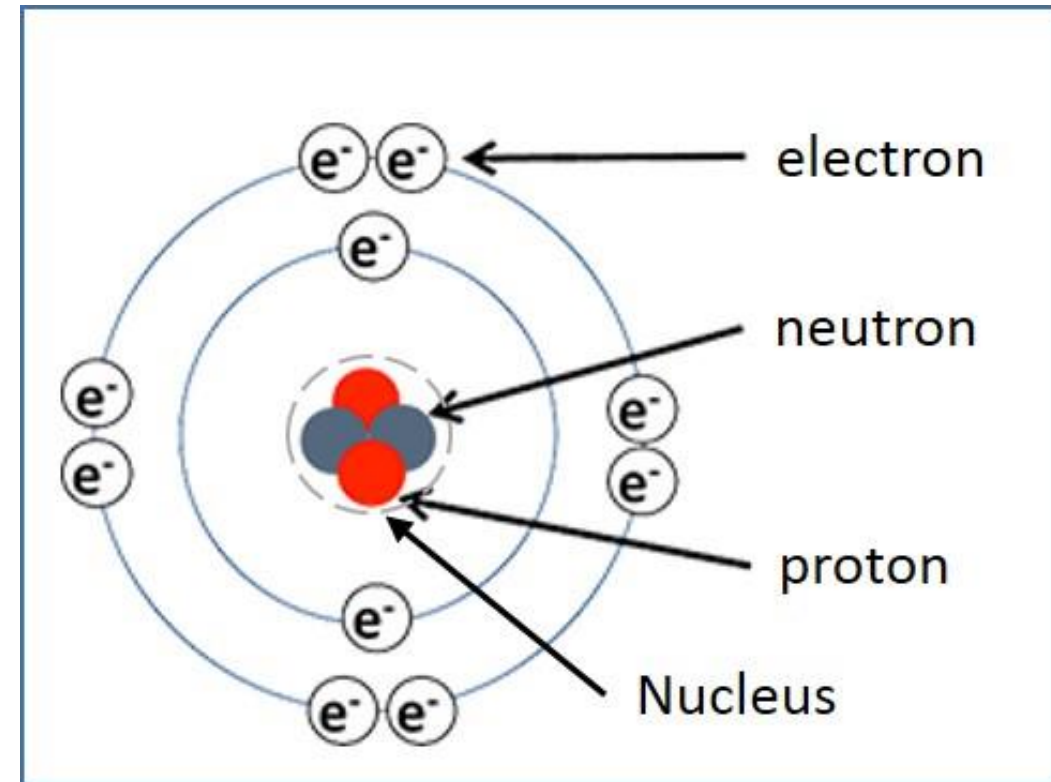
# The Building Block: Atomic Structure

## The Atom:

Subatomic particles: Protons (positive), Neutrons (neutral) in the Nucleus, and Electrons (negative) in orbits/shells.

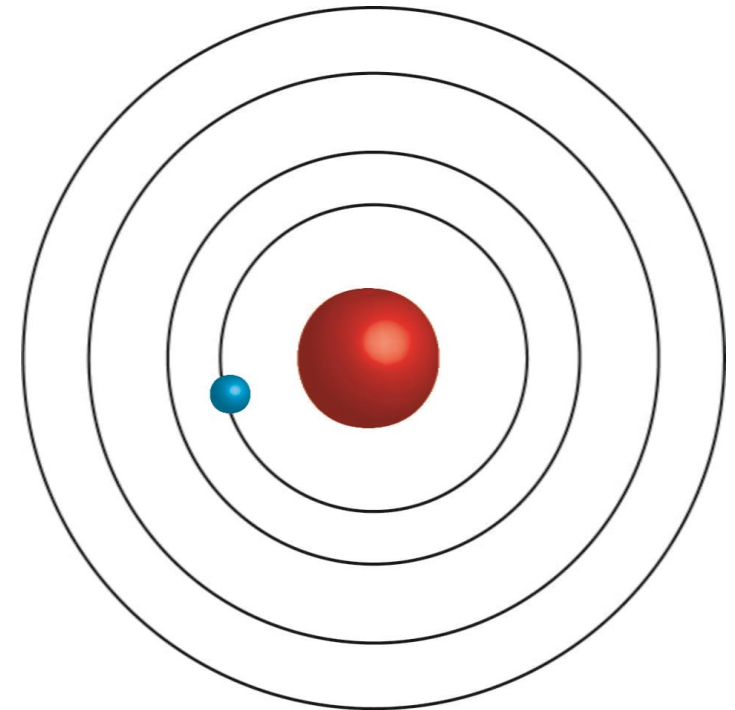
**Atomic Number (Z):** The number of protons in an atom's nucleus.

**Atomic Mass (A):** The total number of protons and neutrons in an atom's nucleus.



# Bohr vs. Wave-Mechanical | Models of the Atom:

Brief introduction to the Bohr Model is a model of the atom that describes electrons as orbiting the nucleus in specific, fixed circular orbits or "energy levels".



# Bohr vs. Wave-Mechanical | Models of the Atom:

## Wave-Mechanical Model

is the current, most accurate theory for describing the behavior and location of electrons within an atom.

It proposes that electrons exhibit both wave-like and particle-like properties (wave-particle duality) and do not orbit the nucleus in fixed, defined paths as earlier models suggested.

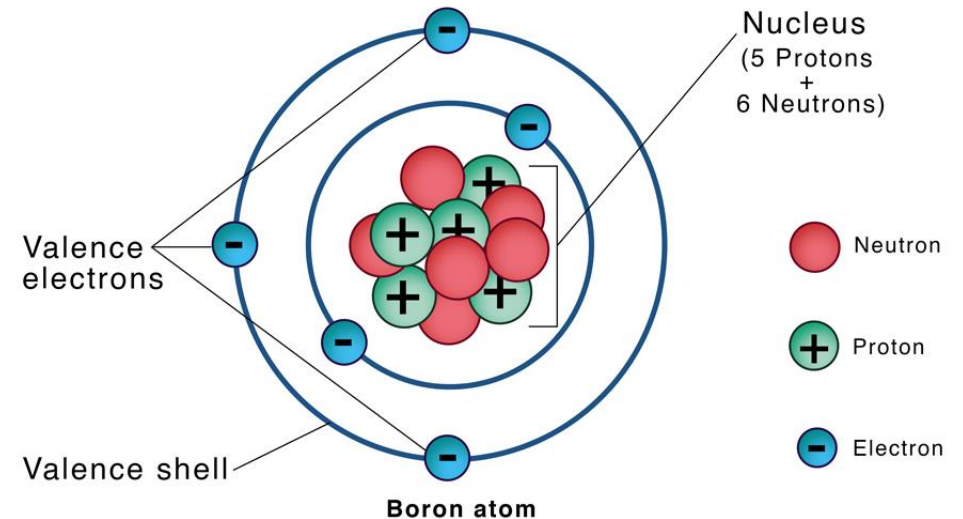
# Electronic Structure and Shells

**Electron Shells (K, L, M,...):** Explaining principal quantum numbers and the maximum number of electrons in each shell ( $2n^2$ ).

## the concept of Valence Electrons

Valence electrons are the electrons located in the outermost electron shell (also known as the valence shell) of an atom. They are the key participants in chemical reactions and bonding, and thus largely determine an element's chemical properties and reactivity.

### Valence Electrons



# The Periodic Table: Organization | Arrangement

## **Atomic Number:**

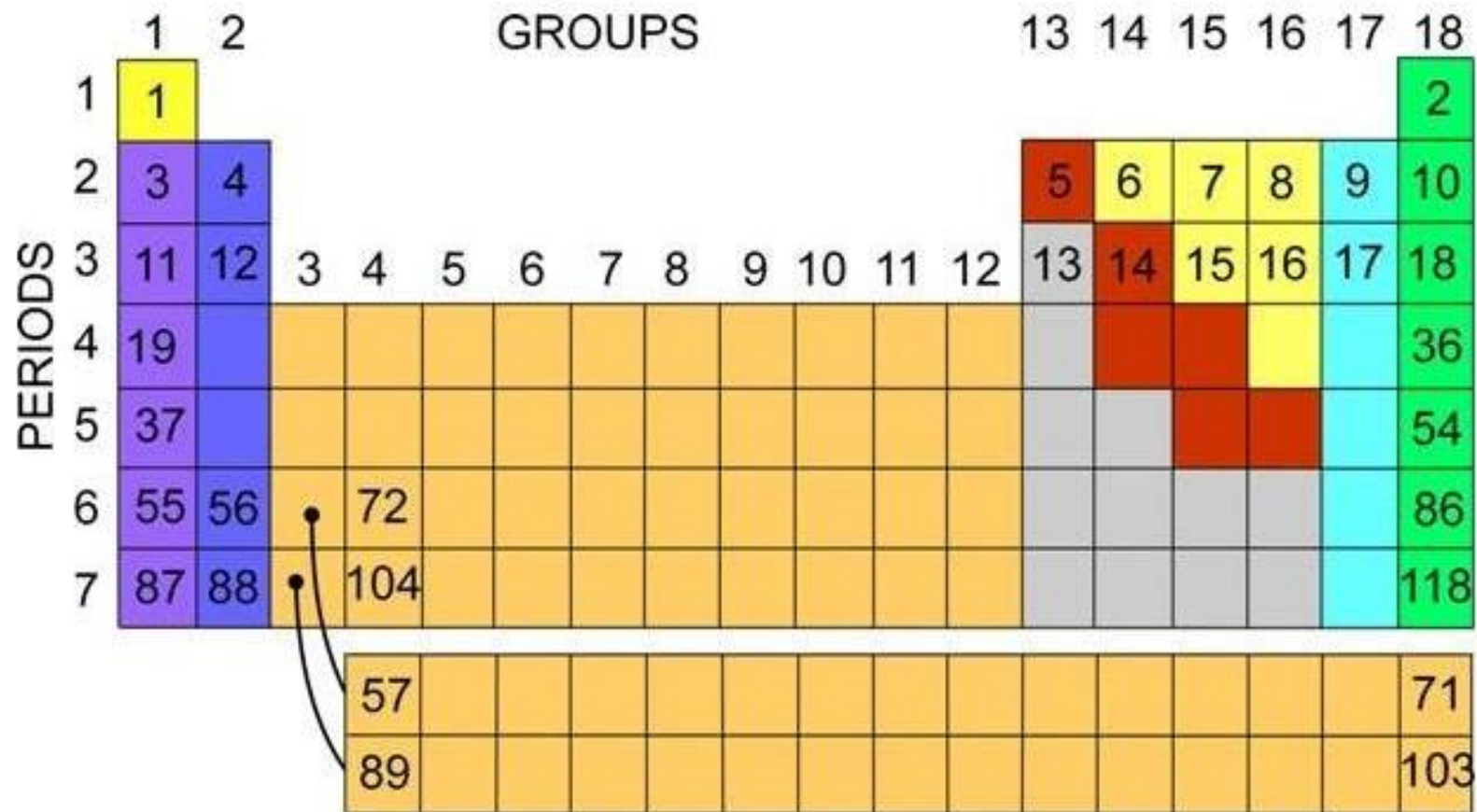
Elements are arranged in order of increasing atomic number, which is the number of protons in an atom's nucleus.

## **Periods:**

The horizontal rows are called periods. Moving across a period, the atomic number increases.

## **Groups:**

The vertical columns are called groups. Elements in the same group share similar chemical properties because they have the same number of valence electrons



Metals:

- Alkali metals
- Alkaline Earth metals
- Transition metals
- Other metals

Non-metals:

- Semi-metals
- Halogens
- Noble gases
- Other non-metals

“Thank You”



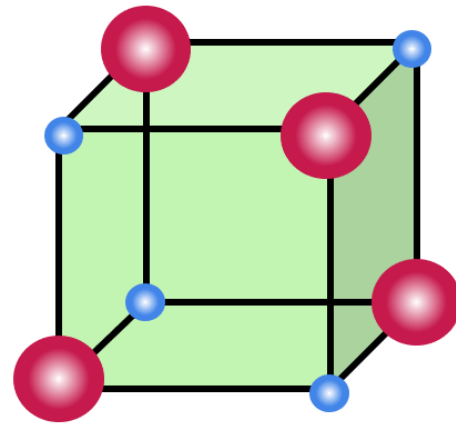
# **Main Content Focus**

**Prof. Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

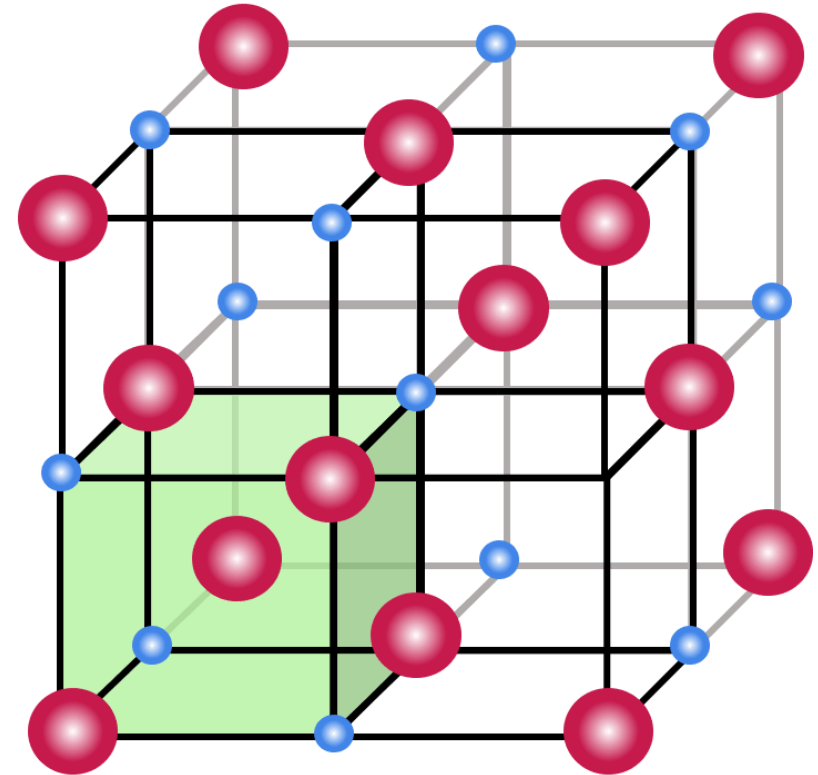
# Defining Crystal Structures | Key Concepts:

**A Unit Cell** is the smallest repeating portion of a crystal lattice that shows the three-dimensional pattern of the entire crystal

Stacking unit cells together without any gaps or overlaps generates the entire crystal structure

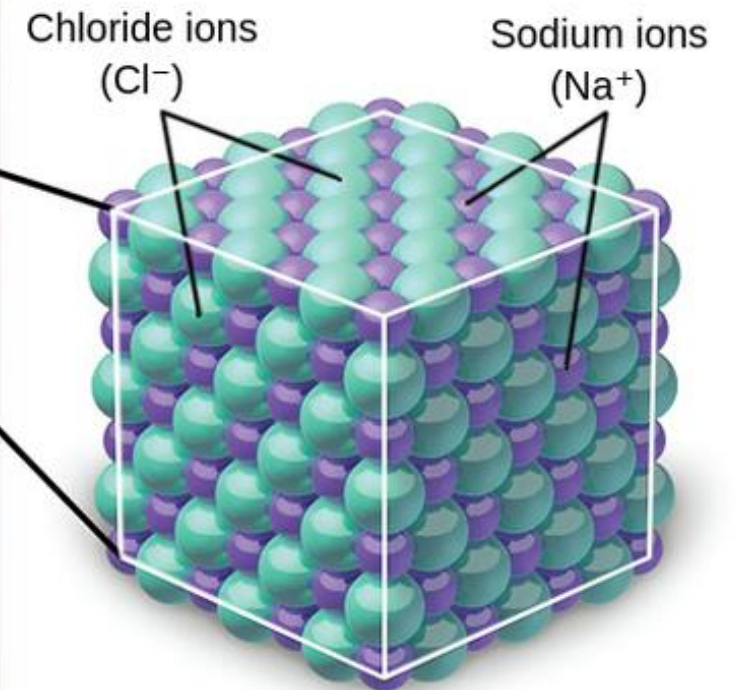
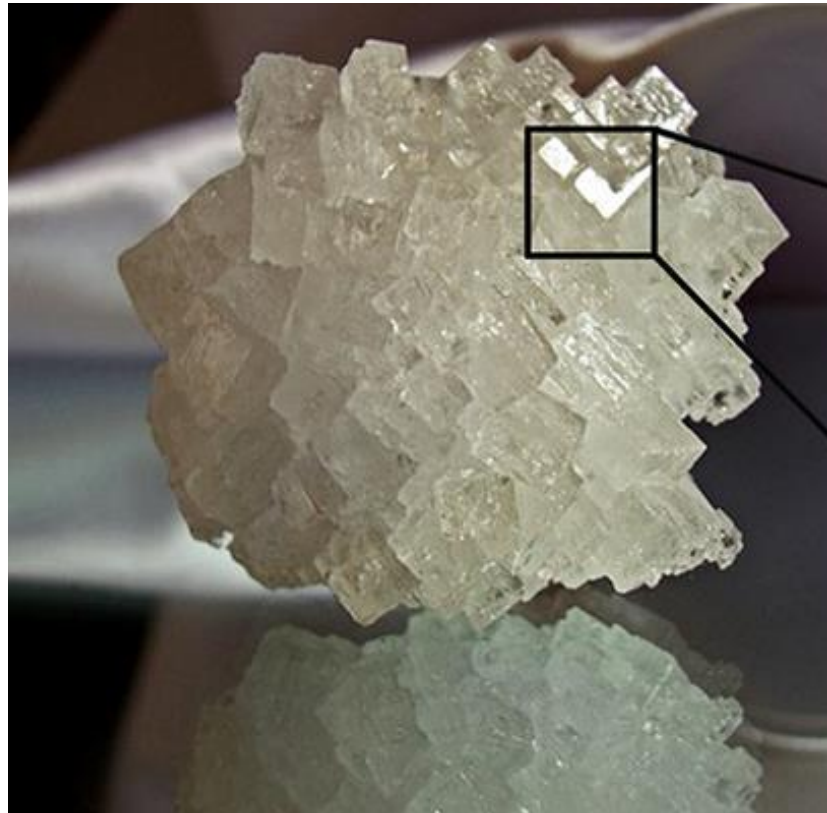


**Unit Cell**



**Crystal Lattice**

- A **Crystal Lattice** is the three-dimensional, ordered arrangement of atoms, ions, or molecules that make up a crystal . It is formed by the regular repetition of the unit cell in space



Sodium Chloride Crystal

- **The Coordination Number (CN)** refers to the number of nearest neighbors surrounding a central atom, ion, or molecule in a crystal lattice or any other structure . It is a key factor in determining the packing efficiency and stability of the crystal .
- **For example**, in a simple cubic lattice, the coordination number is 6, while in a face-centered cubic (FCC) or hexagonal close-packed (HCP) structure, it is 12, representing the most efficient packing possible

# Body-Centered Cubic (BCC) Structure | BCC Geometry:

**The Body-Centered Cubic (BCC) structure** is a crystal arrangement characterized by atoms located at each of the eight corners of a cube, in addition to a single atom positioned precisely in the center of the cube.

This structure is commonly known by the abbreviation BCC

**Mechanical Properties:** BCC metals are typically harder and less malleable than closely packed structures like gold (FCC)

**Example //** chromium, potassium, sodium, vanadium, and tungsten

# BCC Atomic Packing Factor (APF)

The Atomic Packing Factor (APF) for a Body-Centered Cubic (BCC) crystal structure is 0.68 (or 68%). This means that 68% of the total volume of the BCC unit cell is occupied by atoms, while the remaining 32% is empty space (void space).

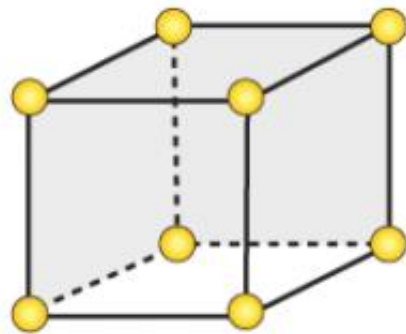
The APF is calculated using the formula:

$$APF = \frac{\text{volume of Atoms}}{\text{Volume of Unit Cell}}$$

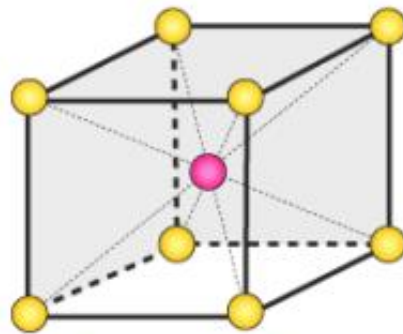
# Face-Centered Cubic (FCC) Structure | FCC Geometry:

The **Face-Centered Cubic (FCC)** structure is a type of crystal lattice with atoms at each corner and the center of each face of a cubic unit cell. It is a close-packed structure, meaning it is one of the most efficient ways to arrange spheres of the same size.

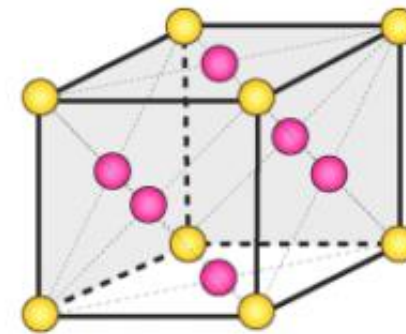
## TYPES OF UNIT CELL



Simple cubic



Body-centred  
Cubic Unit Cell  
(BCC)



Face-centred  
Cubic Unit Cell  
(FCC)

# Physical Properties

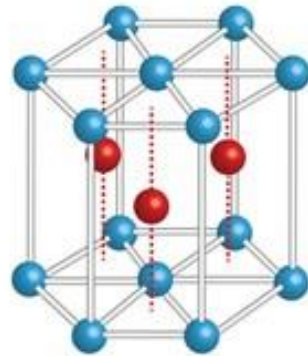
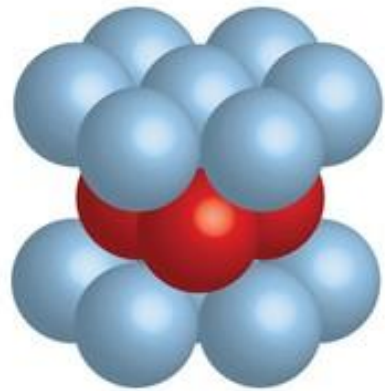
- The efficient packing and high coordination number of FCC structures contribute to several characteristic properties
- **High Ductility/Malleability:** The close-packed planes (specifically the {111} planes) and the large number of available slip systems allow for easier movement of dislocations, enabling the material to deform under stress without breaking.
- **High Density:** Due to the efficient packing of atoms within the unit cell.
- **Good Electrical and Thermal Conductivity:** Common in many FCC metals like copper, gold, and aluminum.

# FCC Atomic Packing Factor (APF) | Calculation:

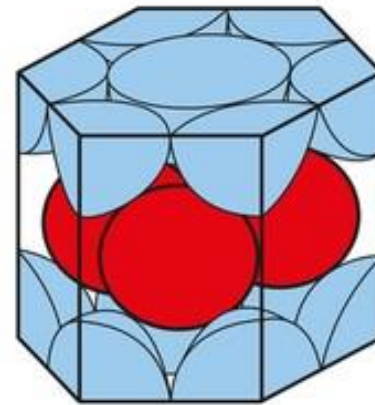
The Atomic Packing Factor (APF) for a Face-Centered Cubic (FCC) crystal structure is 0.74 (or 74%). This is the maximum possible packing efficiency for spheres of the same size.

# Hexagonal Close-Packed (HCP) Structure | HCP Geometry:

The **Hexagonal Close-Packed (HCP) structure** is a crystal lattice arrangement known for its high packing efficiency (74%) and specific geometry. It is one of the two most efficient ways to pack spheres in three-dimensional space, the other being face-centered cubic (FCC).



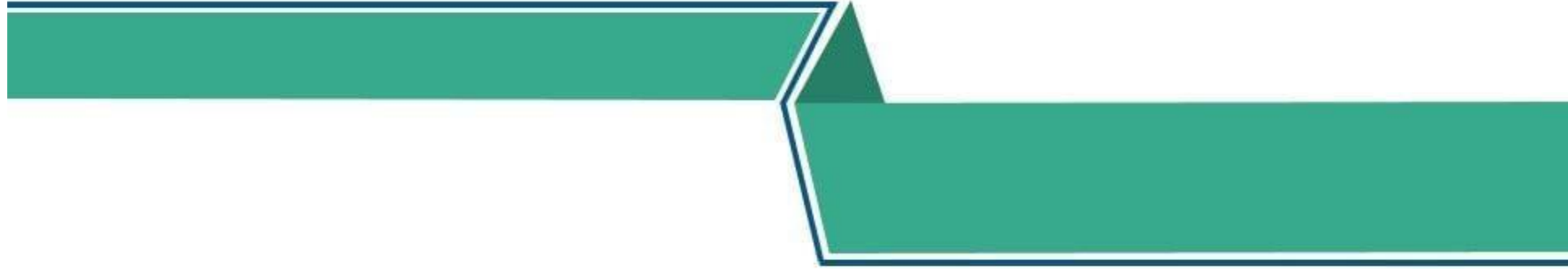
hexagonal (hcp)



# HCP APF and c/a Ratio | APF:

- The ideal Atomic Packing Factor (APF) for a Hexagonal Close-Packed (HCP) structure is 0.74 (or 74%).
- This is the maximum possible packing efficiency for a single-component structure of hard spheres, and is the same as that for a Face-Centered Cubic (FCC) structure.

“Thank You”



# **Defects and Solidification**

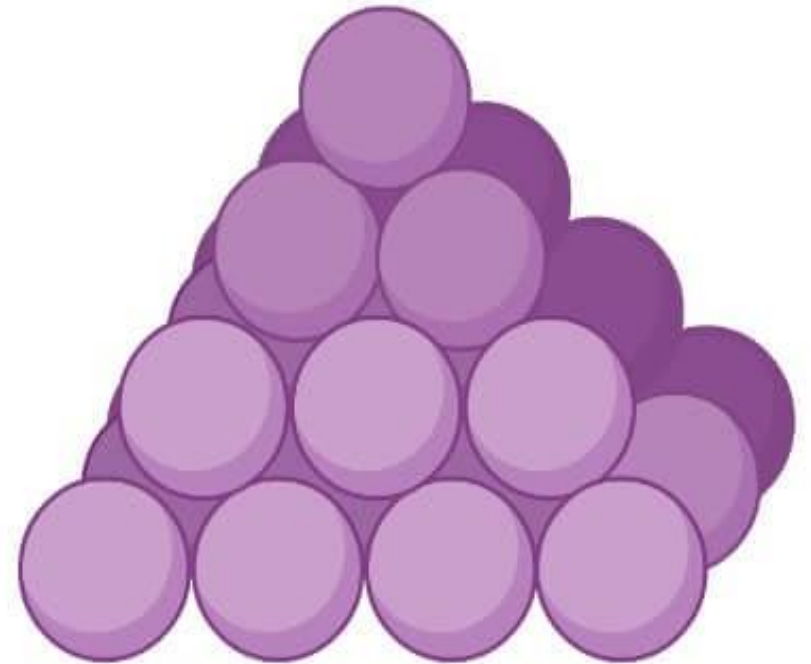
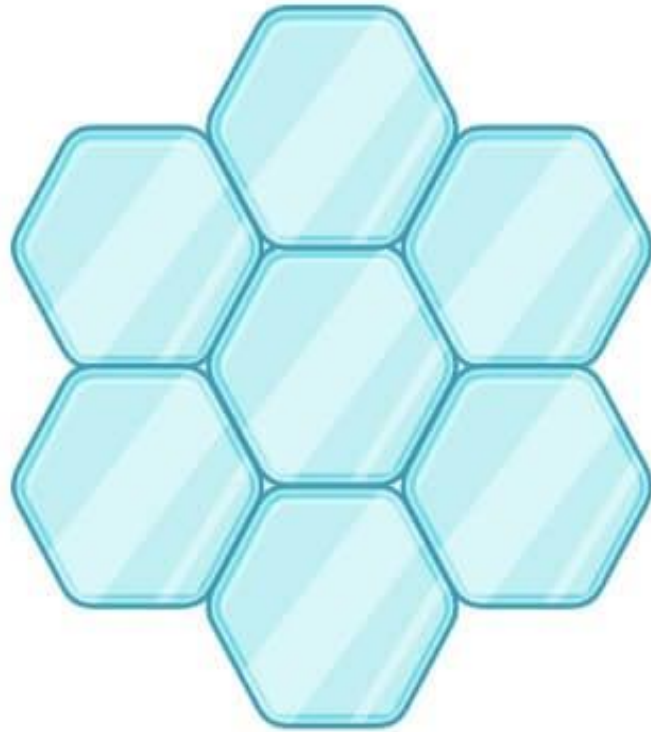
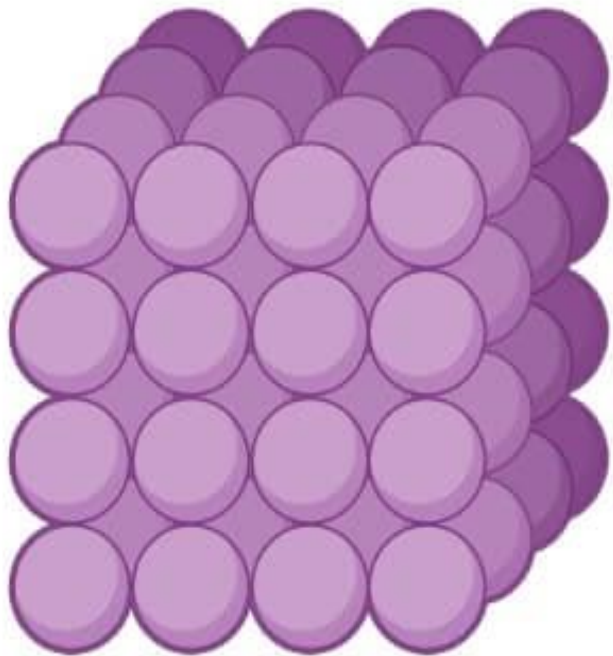
**Prof. Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Introduction to Imperfections in Crystals

Ideal crystals don't exist. Defects are deviations from perfect periodicity. Emphasize that defects are not always bad; they often govern material properties (e.g., strength).

# Crystals Defects

**Causes, Types, Factors, Importance**



# Zero-Dimensional (0D) Defects: Point Defects

Types:

1. Vacancy (Missing atom).
2. Interstitial (Extra atom squeezed into a void).
3. Substitutional (Impurity atom replacing a host atom).

# One-Dimensional (1D) Defects: Dislocations

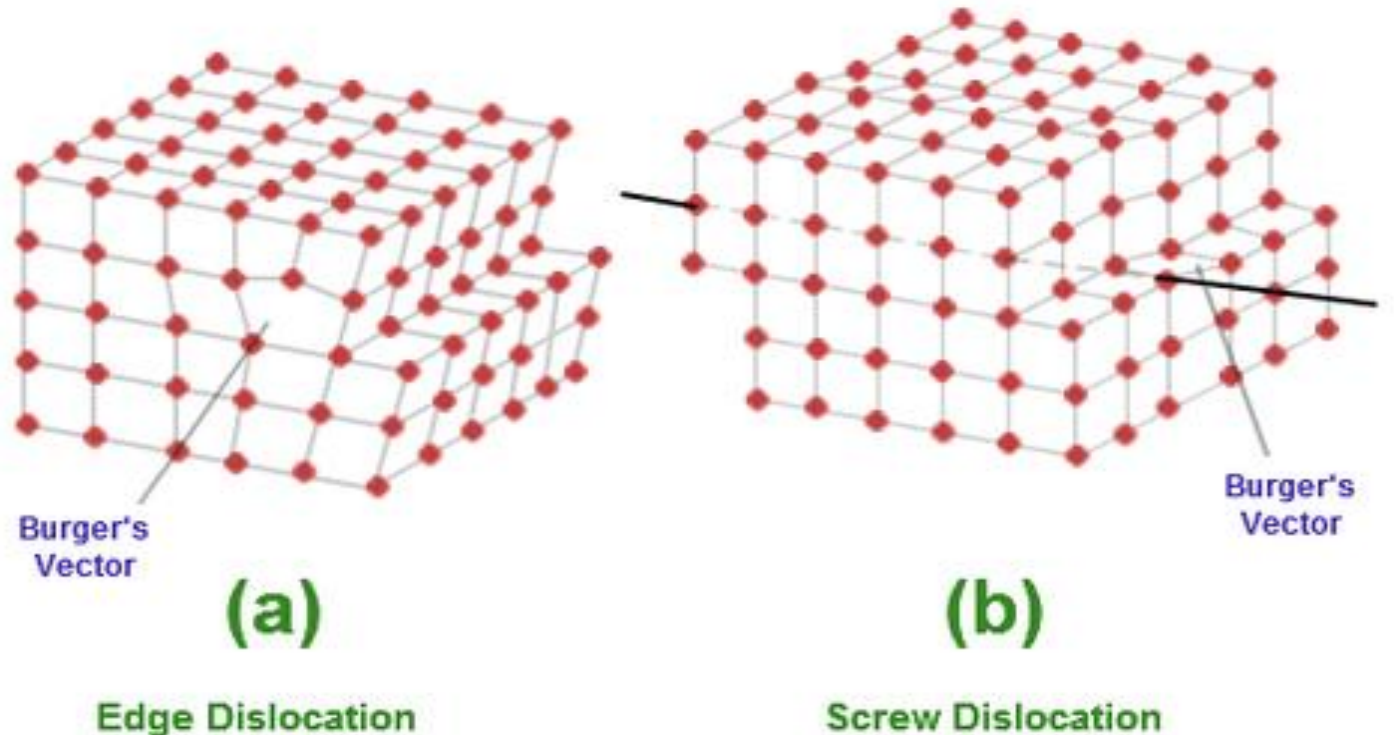
Definition: Linear or line defects.

Importance: Dislocations explain why metals deform plastically (change shape permanently) at stresses much lower than the theoretical bond strength

# Types of Dislocations

Types:

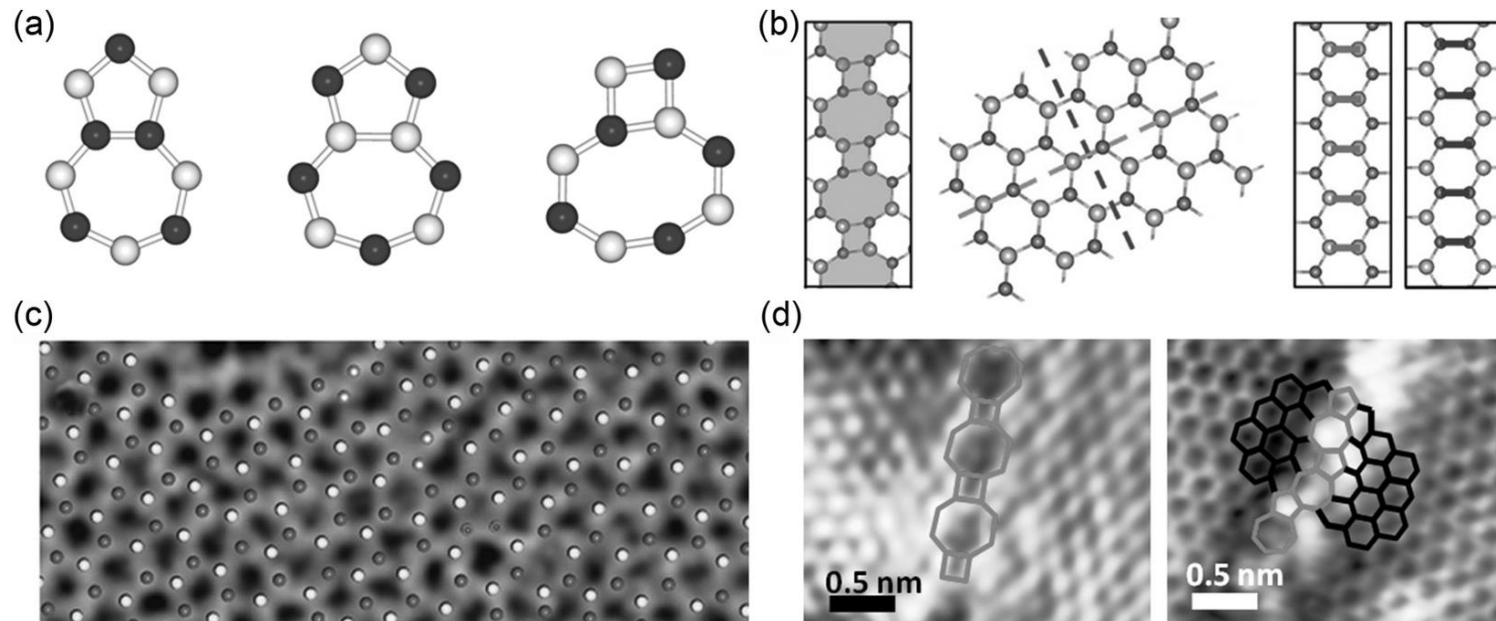
1. Edge Dislocation (Extra half-plane of atoms).
2. Screw Dislocation (Spiral atomic arrangement).



# Two-Dimensional (2D) Defects: Grain Boundaries

Definition: Interfaces separating regions of different crystallographic orientation (Grains).

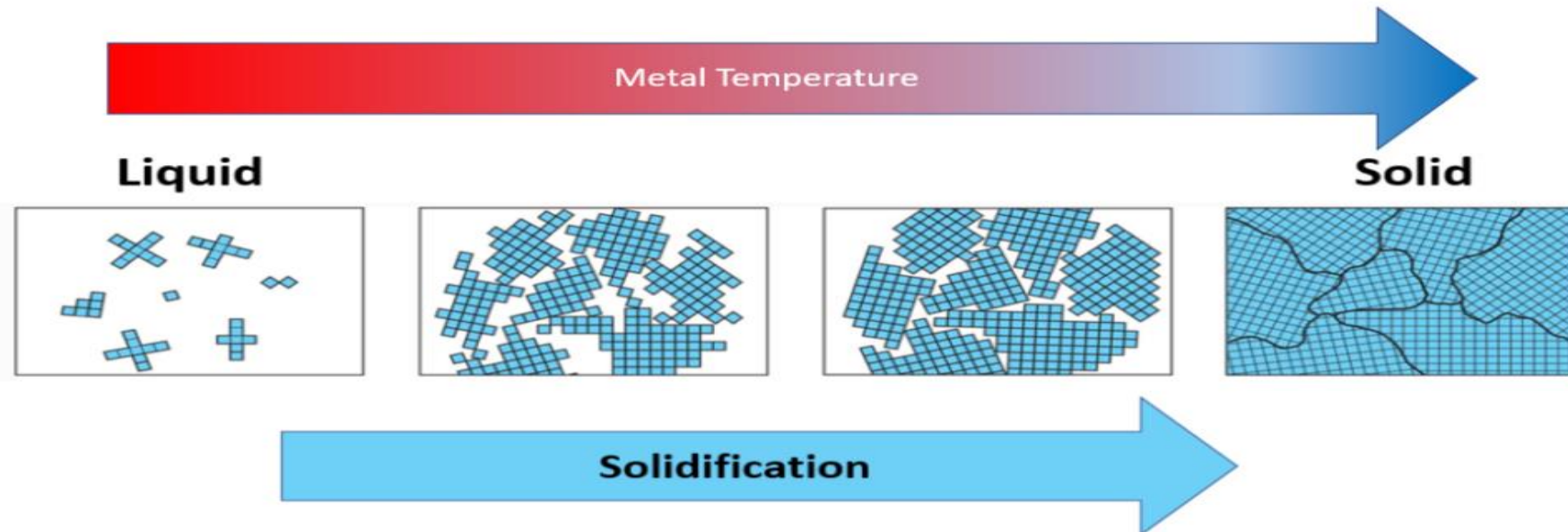
Impact: Grain boundaries impede dislocation motion, thus strengthening the material (Hall-Petch strengthening).



# Introduction to Solidification of Metals

The transformation of a molten liquid into a solid crystalline structure.

**Importance:** The process dictates the final microstructure and, consequently, the final properties of the casting/metal.



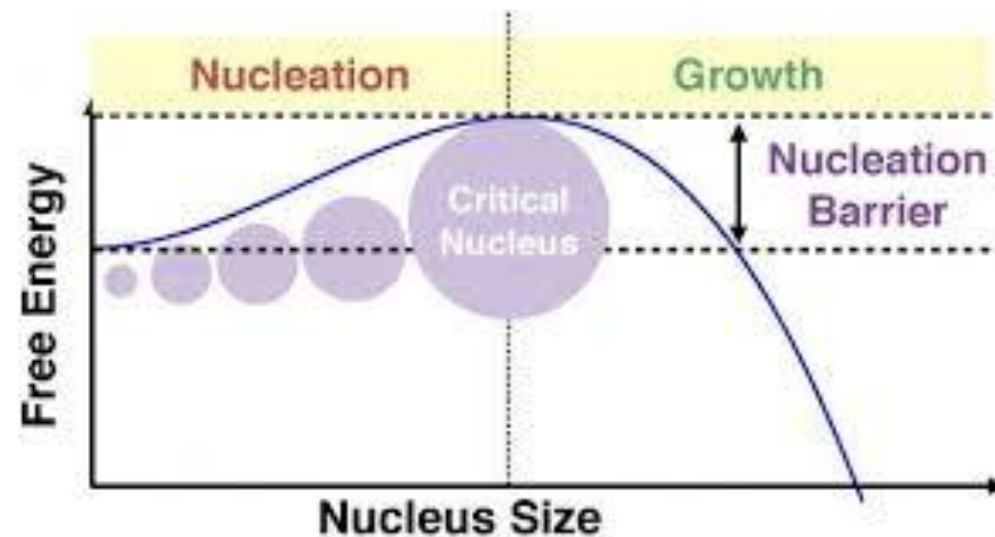
# The Solidification Process: Nucleation

## Stage 1:

Nucleation: Formation of stable small solid particles (Nuclei) within the liquid.  
Types: Homogeneous (spontaneous) vs. Heterogeneous (on molds/impurities).

## Stage 2:

Growth: Nuclei grow by adding atoms from the liquid, forming the Grains.



# Solidification of Alloys

Alloys solidify over a range of temperatures (not a single melting point).

**Solidification range:** Alloys solidify over a range between the liquidus temperature (where solidification begins) and the solidus temperature (where it is complete).

**Mushy zone:** In the temperature range between the liquidus and solidus, the alloy exists as a mixture of liquid and solid phases, known as the mushy zone.

**Microstructure:** The resulting solid structure is crystalline and often forms distinct zones: a fine-grained chill zone at the mold wall, a columnar zone with elongated grains, and an equiaxed zone with roughly spherical grains in the center.

**Dendritic structure:** As alloys cool, crystals often grow in a tree-like, or dendritic, pattern, especially in the columnar zone.

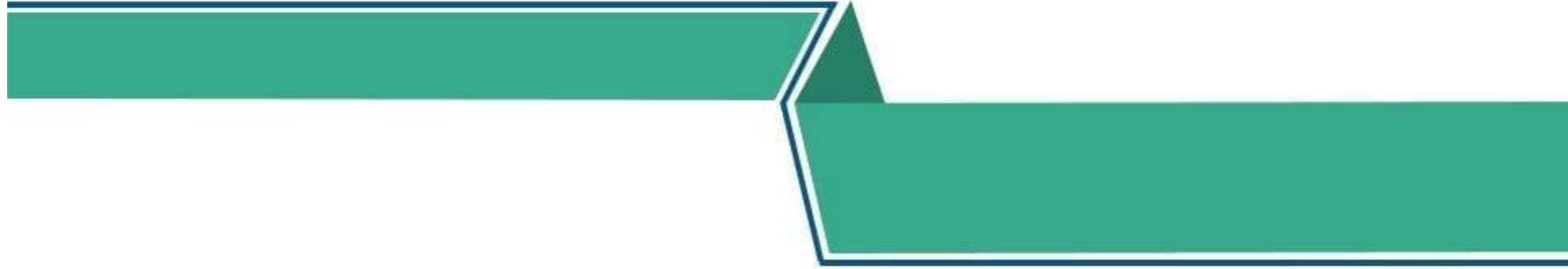
**Phase diagrams:** These diagrams are crucial for understanding alloy solidification as they show the phases present at different temperatures and compositions and define the liquidus and solidus lines.

# Influencing factors

The final microstructure is influenced by several factors, including:

1. the degree of supercooling
2. the thermal gradient  $G$
3. the rate of cooling  $R$
4. The ratio of  $G/R$  is particularly important in determining the type of crystal growth.

“Thank You”



# **Atomic Scale and Bonding**

**Prof Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Introduction to Interatomic Bonding

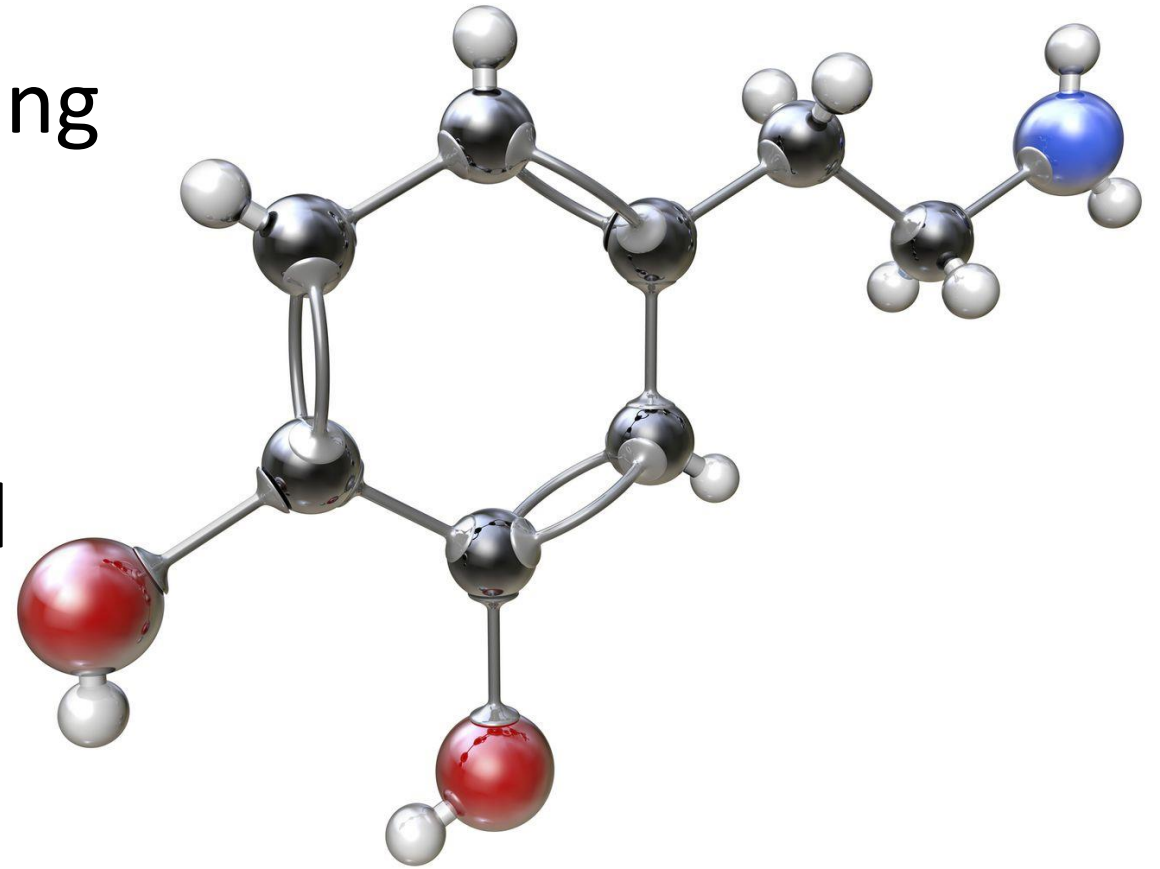
**Atoms bond to achieve a more stable electron configuration (usually a full outer shell).**

**Bonding energy:** (also referred to as bond energy, binding energy, or bond enthalpy) is defined as the minimum amount of energy required to separate two bonded atoms (or one mole of bonded atoms) to an infinite distance.

**Bonding force:** refers to the net electrostatic force (attractive and repulsive components) that two atoms exert on each other.

# Primary Bonds: Strong Forces

Definition: Chemical bonds involving the transfer or sharing of valence electrons. These bonds are strong and require high energy to break, leading to high melting points and stiffness

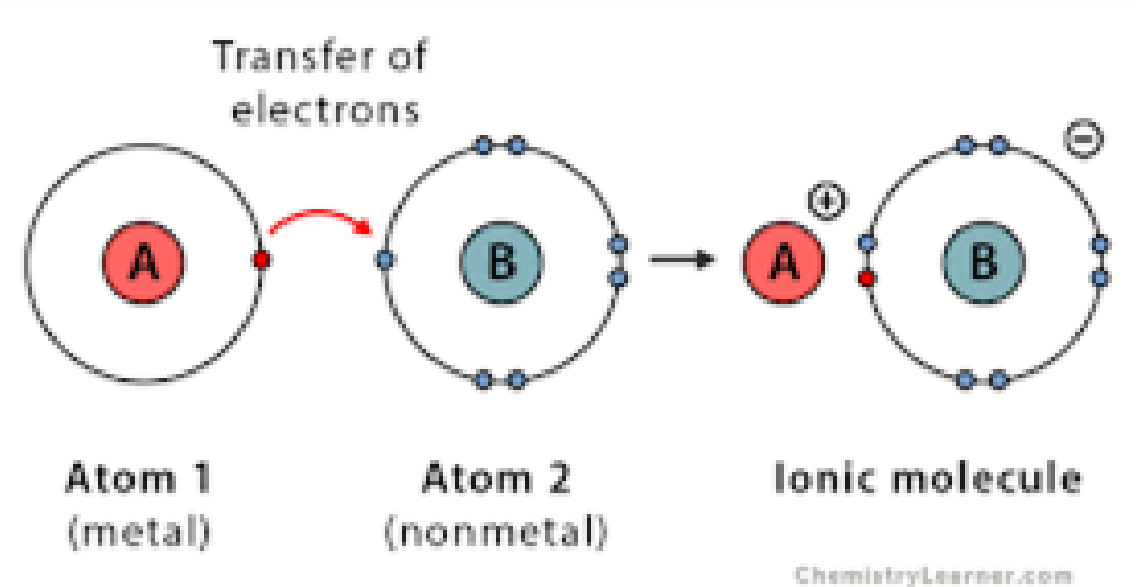


# Ionic Bond (Electrostatic Attraction)

**Mechanism:** Transfer of electrons from a metal (low electronegativity) to a non-metal (high electronegativity), creating ions (cations/anions).

## Characteristics:

Non-directional, occurs in Ceramics (e.g., NaCl)

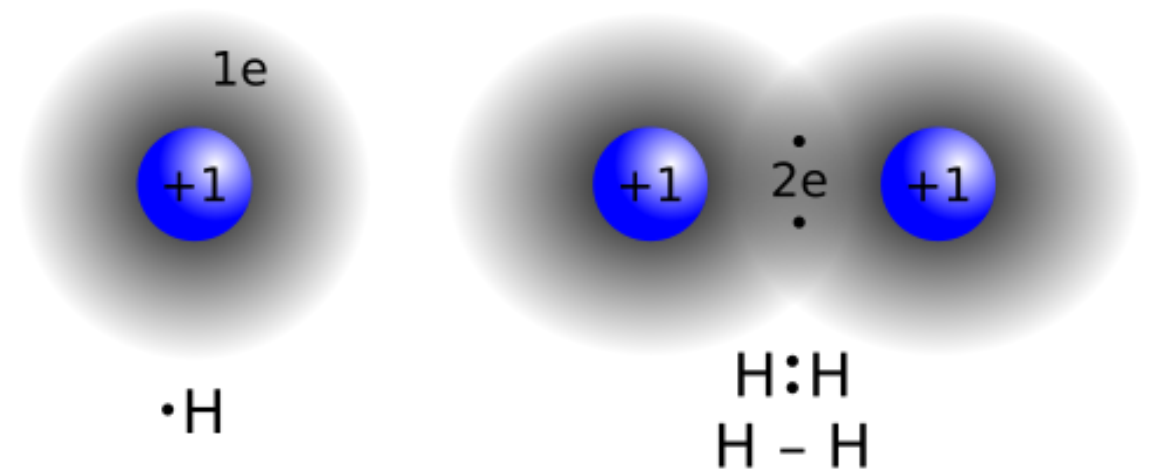


# Covalent Bond (Electron Sharing)

**Mechanism:** Sharing of valence electrons between adjacent atoms to complete their outer shells.

**Characteristics:**

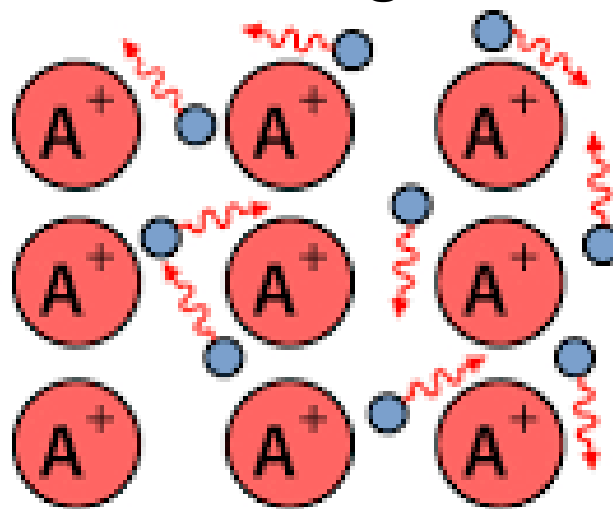
Highly Directional, strong. Occurs in Polymers and many Semiconductors (e.g., Diamond, Si).



# Metallic Bond (The "Sea" of Electrons)

**Mechanism:** Valence electrons are delocalized, forming an electron "Sea" shared by all positively charged ion cores.

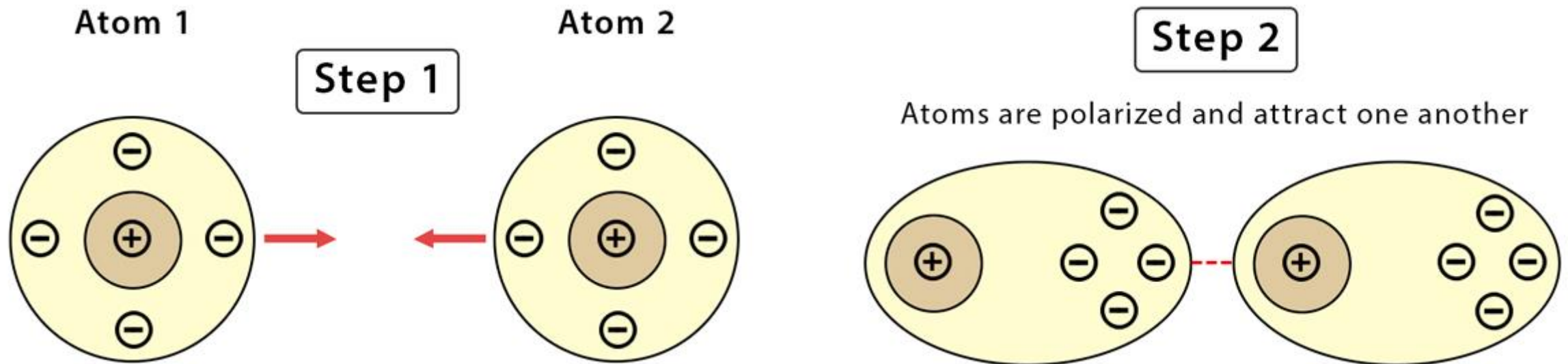
**Characteristics:** Non-directional, accounts for high ductility and conductivity in Metals.



Electrostatic attraction between  
the electrons (●) and metal ions (A<sup>+</sup>)

# Secondary (Van der Waals) Bonds: Weak Forces

**Definition:** Physical bonds resulting from atomic/molecular dipoles. These are much weaker than primary bonds but crucial for polymers and condensed noble gases.



# Types of Secondary Bonds

## **Categories:**

1. London Dispersion
2. Dipole-dipole forces
3. Hydrogen Bond

Van der Waals forces

Permanent dipole-dipole bonds

Hydrogen bonding

London dispersion forces (often simply referred to as Van der Waals bonds)

Exists between all atoms and molecules.

Between polar molecules

Occurs between molecules where a H atom is directly bonded to an atom of N, O or F

# London dispersion forces

The weakest type, present in all atoms and molecules. They are caused by the random movement of electrons, which creates temporary, instantaneous dipoles that can induce dipoles in neighboring molecules

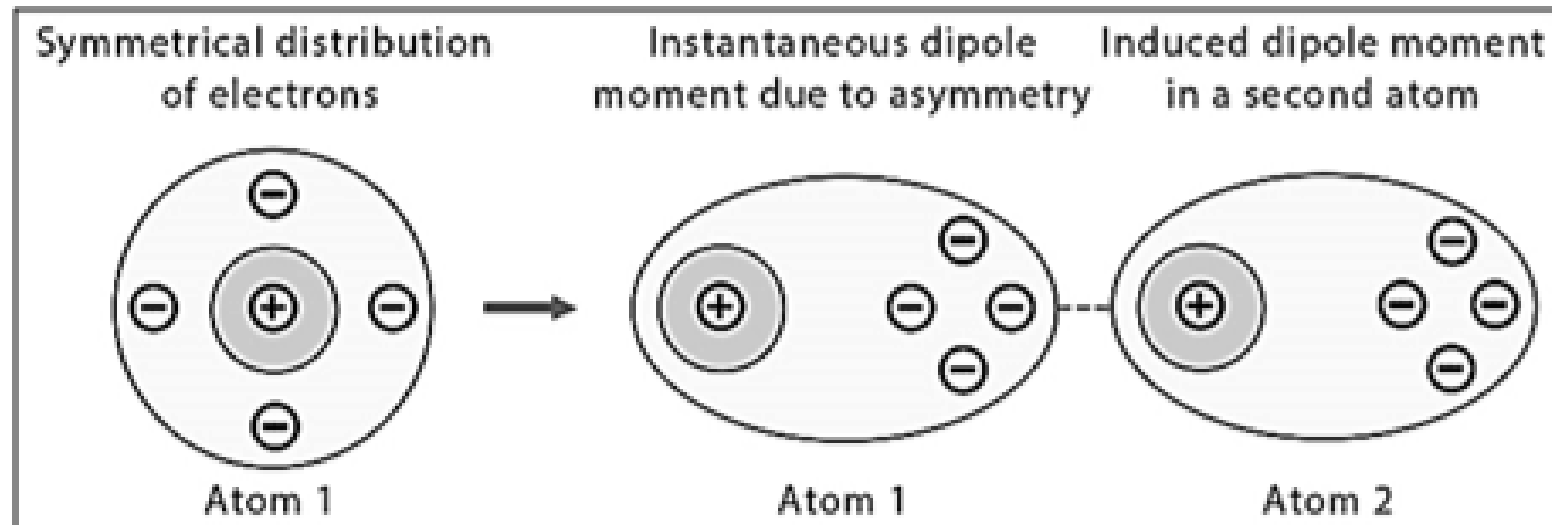
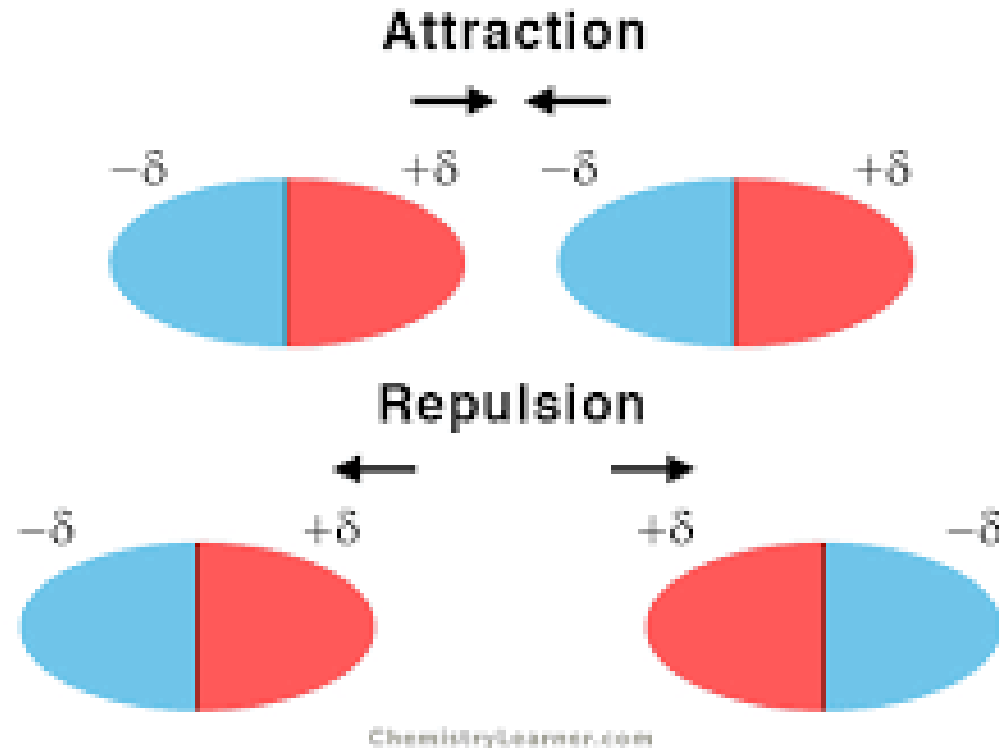


Figure 1: London dispersion forces

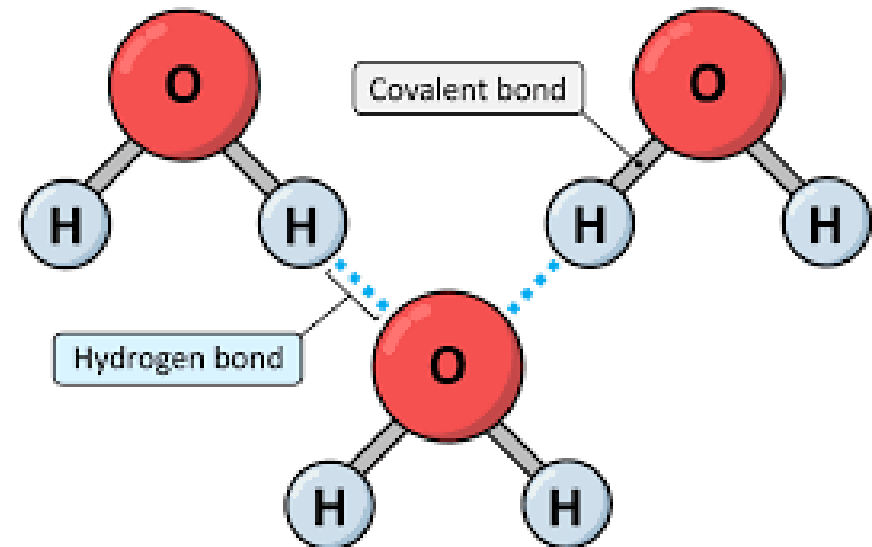
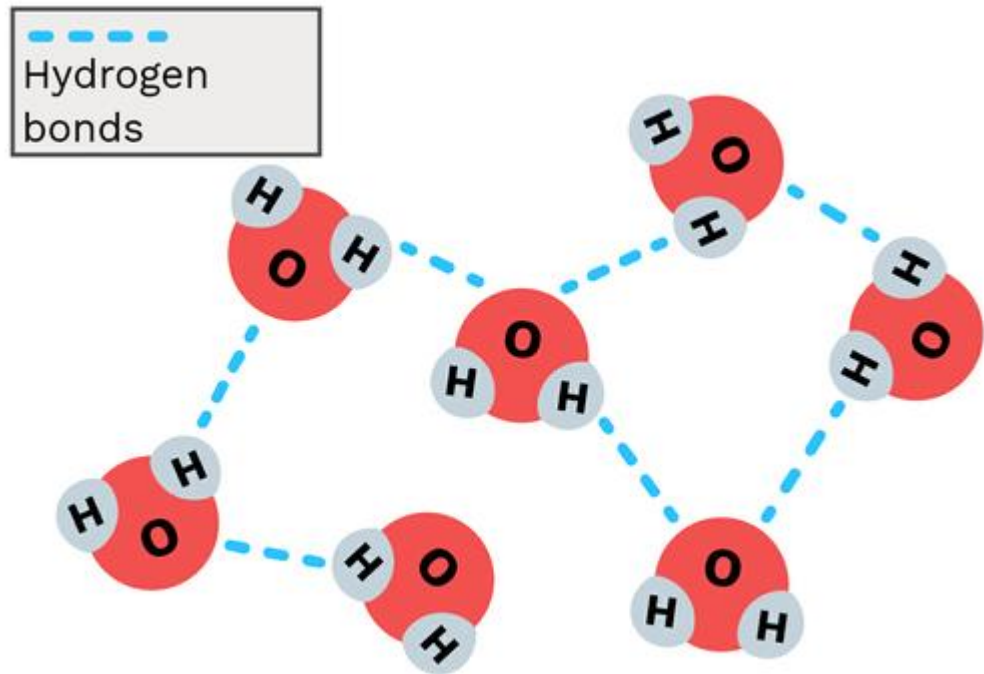
# Dipole-dipole forces

Occur between polar molecules that have permanent positive and negative ends. The positive end of one molecule attracts the negative end of another



# Hydrogen Bond

**Hydrogen Bond:** A special, relatively strong dipole-dipole interaction involving Hydrogen and a highly electronegative atom (F, O, N). Crucial for water and Polymer structure.



“Thank You”

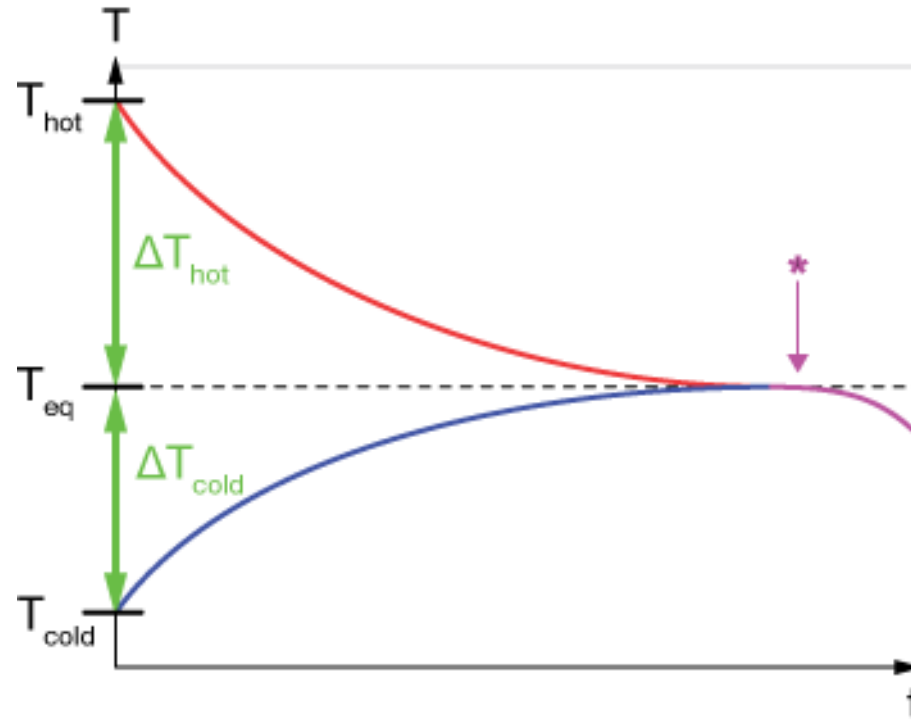


# **Phase Diagrams and Alloys**

**Prof Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Introduction to Thermal Equilibrium Diagrams

**Definition:** Also called Phase Diagrams. Graphical representation showing the phases present in a material system (alloy) under different conditions of Temperature, Composition, and Pressure

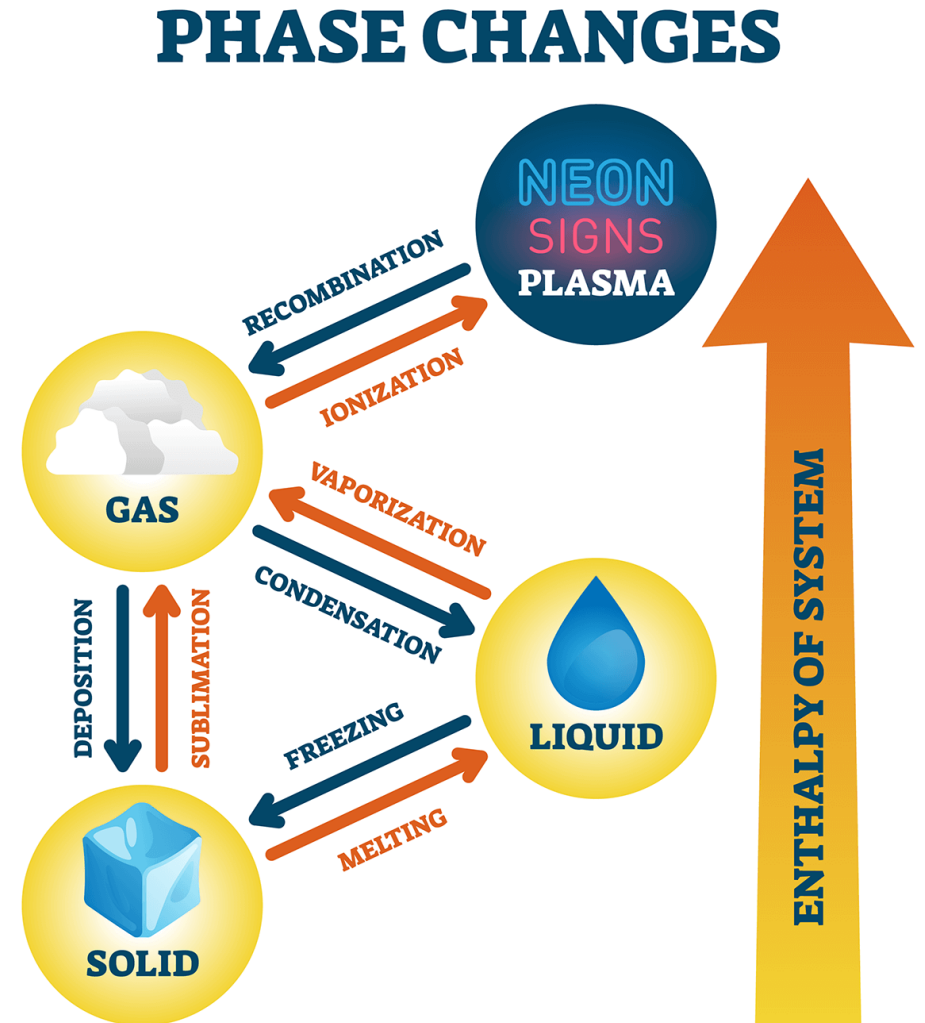


# Defining a Phase

## What is a Phase?

A homogeneous portion of a system that has uniform physical and chemical characteristics.

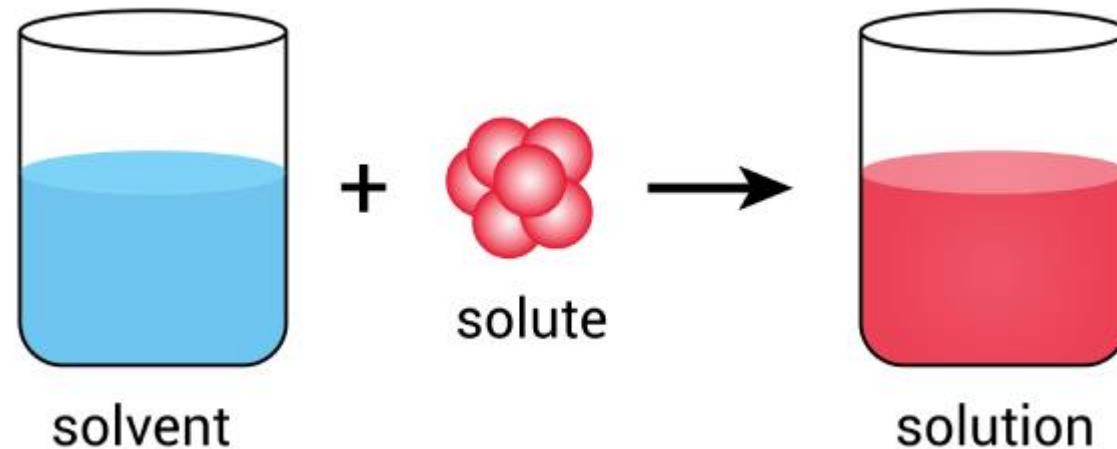
**Examples:** Liquid water, ice,  $\alpha$ -iron (BCC),  $\gamma$ -iron (FCC).



# Components and Solubility

**Components:** The pure metals or compounds that make up the system (e.g., Copper and Nickel in a Cu-Ni alloy).

**Solubility:** The maximum amount of one component that can dissolve in another.



# Solid Solutions

**Definition:** A homogeneous crystalline phase containing two or more elements where the atoms of the solute are dispersed uniformly within the crystal lattice of the solvent.

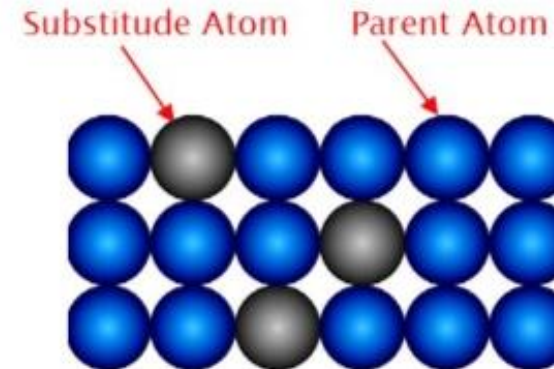
**Types:**

Substitutional

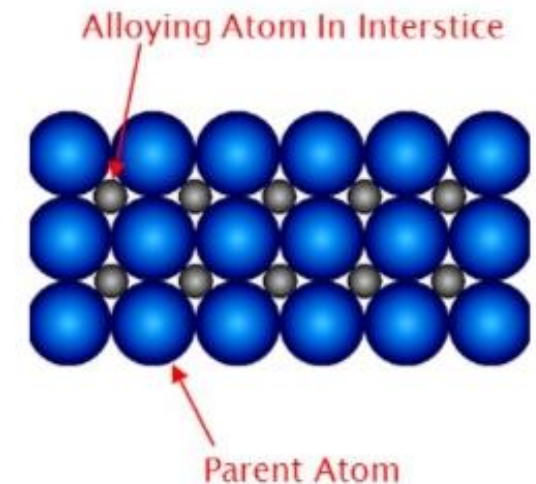
Interstitial

## 2 Types of Solid Solutions

Substitutional Solid Solution Alloys



Interstitial Solid Solution Alloys

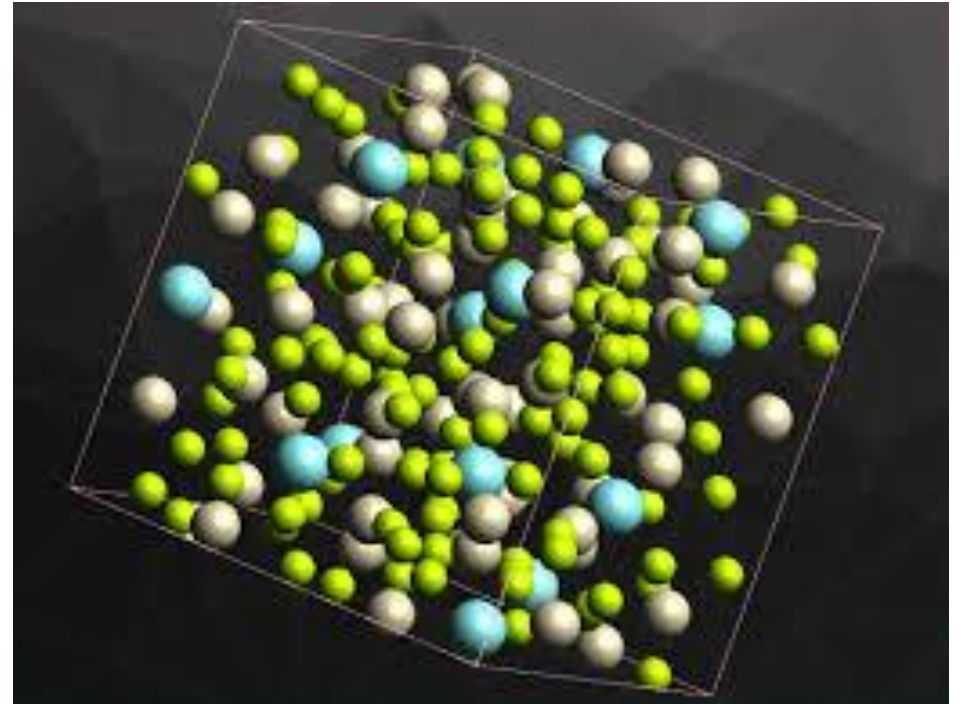


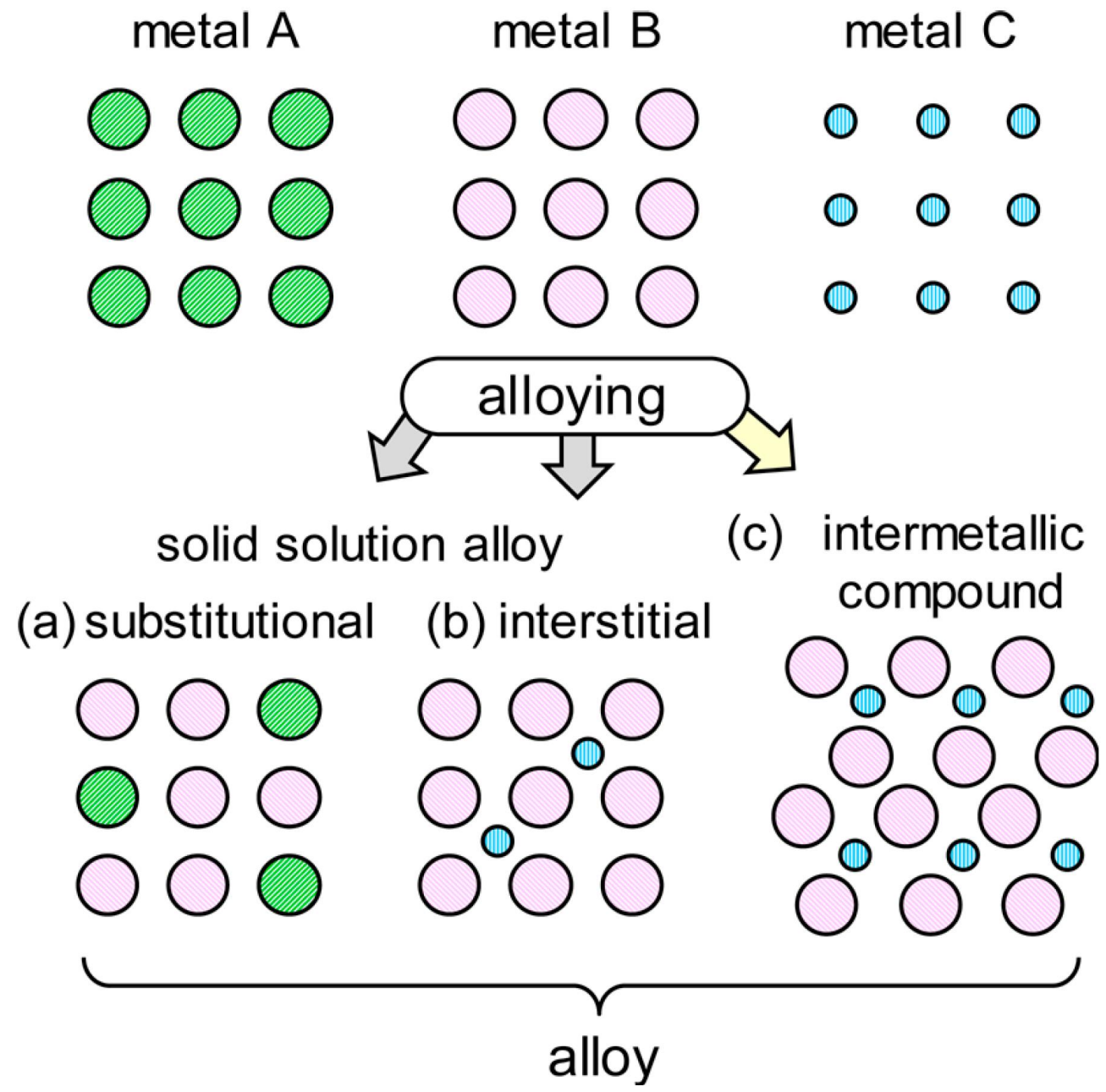
# Intermetallic Compounds

**Definition:** Discrete phases with specific compositions, distinct crystal structures, and definite chemical formulas

(e.g., Fe<sub>3</sub>C or cementite in steel).

They are chemically well-defined.





# Mechanical Mixtures (Phase Mixtures)

**Definition:** Physical mixtures of two or more distinct phases

(e.g., a mixture of  $\alpha$  and  $\beta$  solid solutions).

Their overall properties are often an average of the constituent phases.

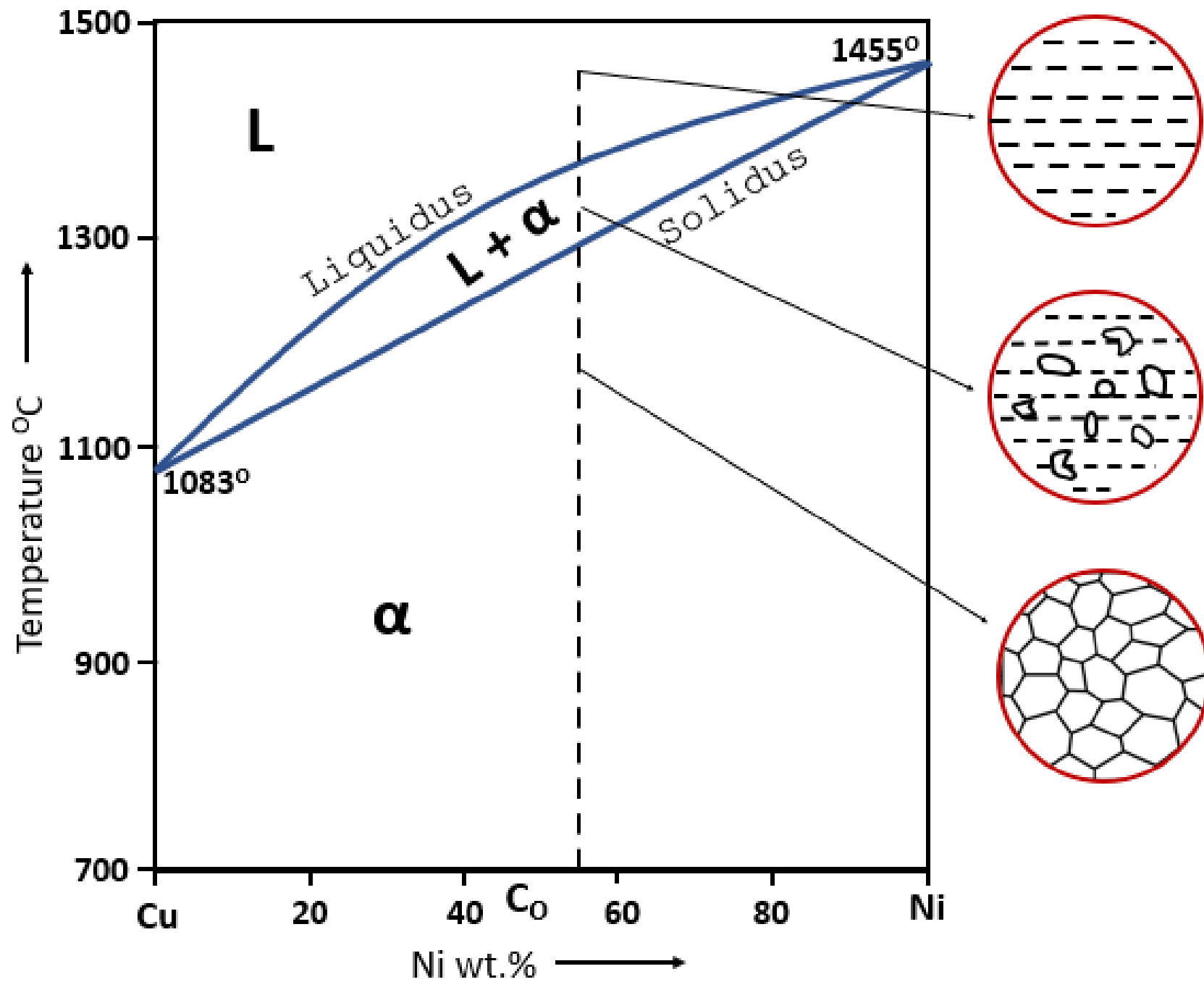


# The Isomorphous Phase Diagram (Simple Case)

## **Example:**

Cu-Ni System: Introduce the simplest binary diagram where components are completely soluble in both liquid and solid states.

Identify the Liquid (L), Solid ( $\alpha$ ),  
and Liquid + Solid (L +  $\alpha$ ) regions.



## The Tie Line Rule

### Application:

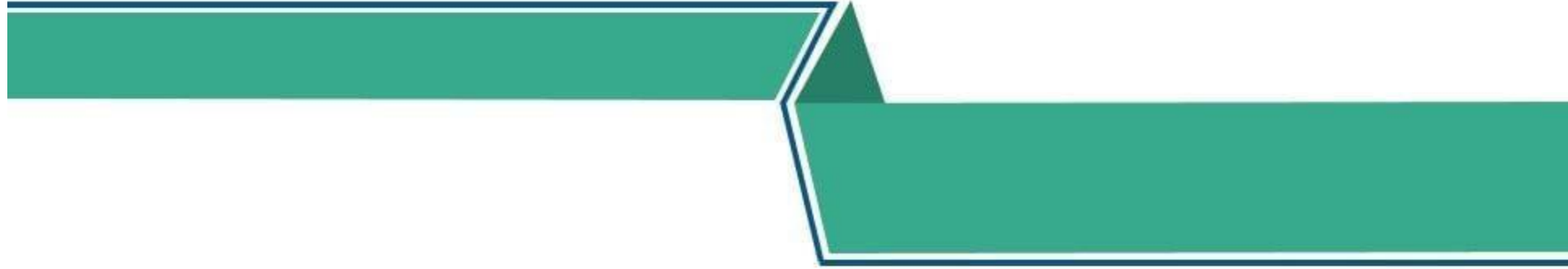
to determine the Composition of each phase ( $\alpha$  and L) at a given temperature

## The Lever Rule

### Application:

to calculate the Relative Amounts (Fractions) of each phase ( $\alpha$  and L) present at a specific temperature and overall composition. (Crucial for quantitative analysis)

“Thank You”



# **Advanced Phase Diagrams**

**Prof. Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Applications of Phase Diagrams

1. Alloy design and development
2. Heat treatment control
3. Separation and purification processes
4. Preservation and manufacturing
5. Predicting phase behavior

# The Gibbs Phase Rule

a fundamental principle in thermodynamics that connects the number of phases (P), components (C), and degrees of freedom (F) in a system at thermodynamic equilibrium, expressed as  $F = C - P + 2$ , where '2' represents temperature and pressure

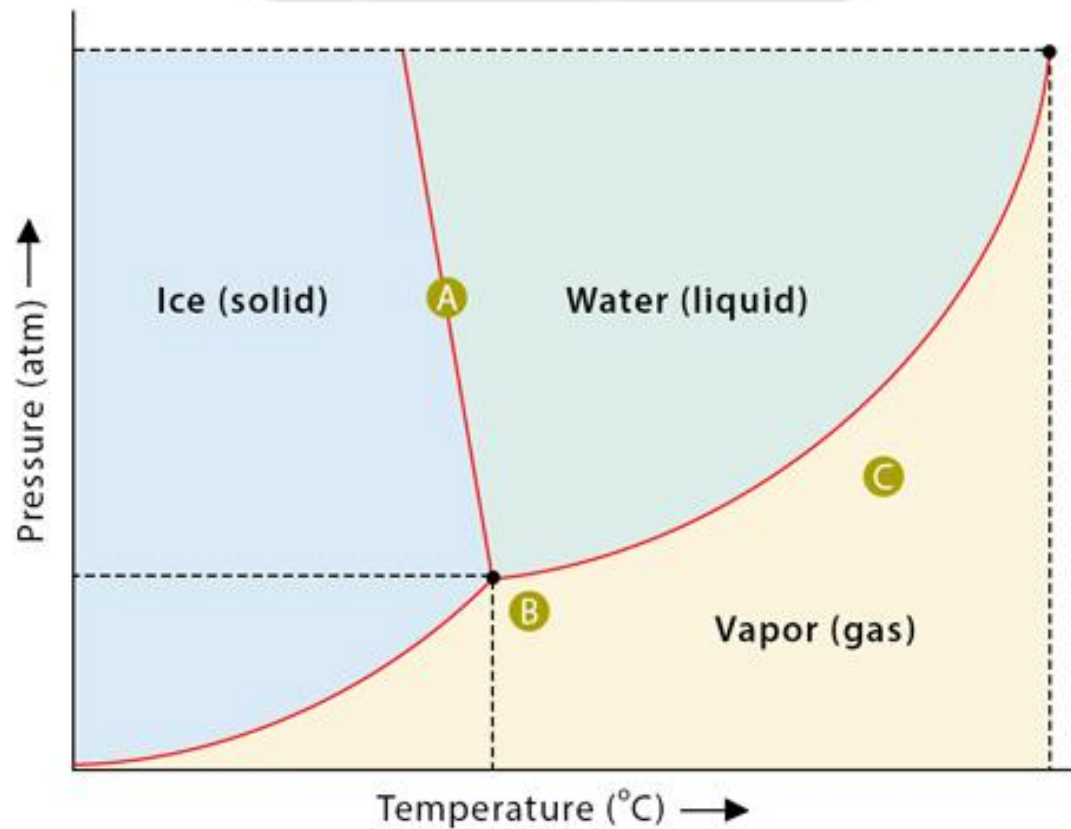
# Application of Gibbs Phase Rule

**interpretation and construction of phase diagrams** across various scientific and engineering disciplines.

Interpretation involves identifying and understanding the different regions and boundaries in a diagram

## Gibbs Phase Rule

Example: Phase Diagram of Water



$$F = C - P + 2$$

Where:

F: degrees of freedom

C: number of components

P: number of phases

| Point | No. of components (C) | No. of phases (P) | Degrees of Freedom  |
|-------|-----------------------|-------------------|---------------------|
| A     | 1                     | 2                 | $F = 1 - 2 + 2 = 1$ |
| B     | 1                     | 3                 | $F = 1 - 3 + 2 = 0$ |
| C     | 1                     | 1                 | $F = 1 - 1 + 2 = 2$ |

# Example of Phase Diagrams

**Water (H<sub>2</sub>O):** A classic unary (single-component) phase diagram showing the solid (ice), liquid, and vapor regions. It illustrates unique properties, such as the solid-liquid boundary having a negative slope, meaning ice melts at a lower temperature under higher pressure (relevant to glacier movement). It also shows the **triple point**, where solid, liquid, and gas coexist in equilibrium, and the **critical point**, above which liquid water cannot exist.

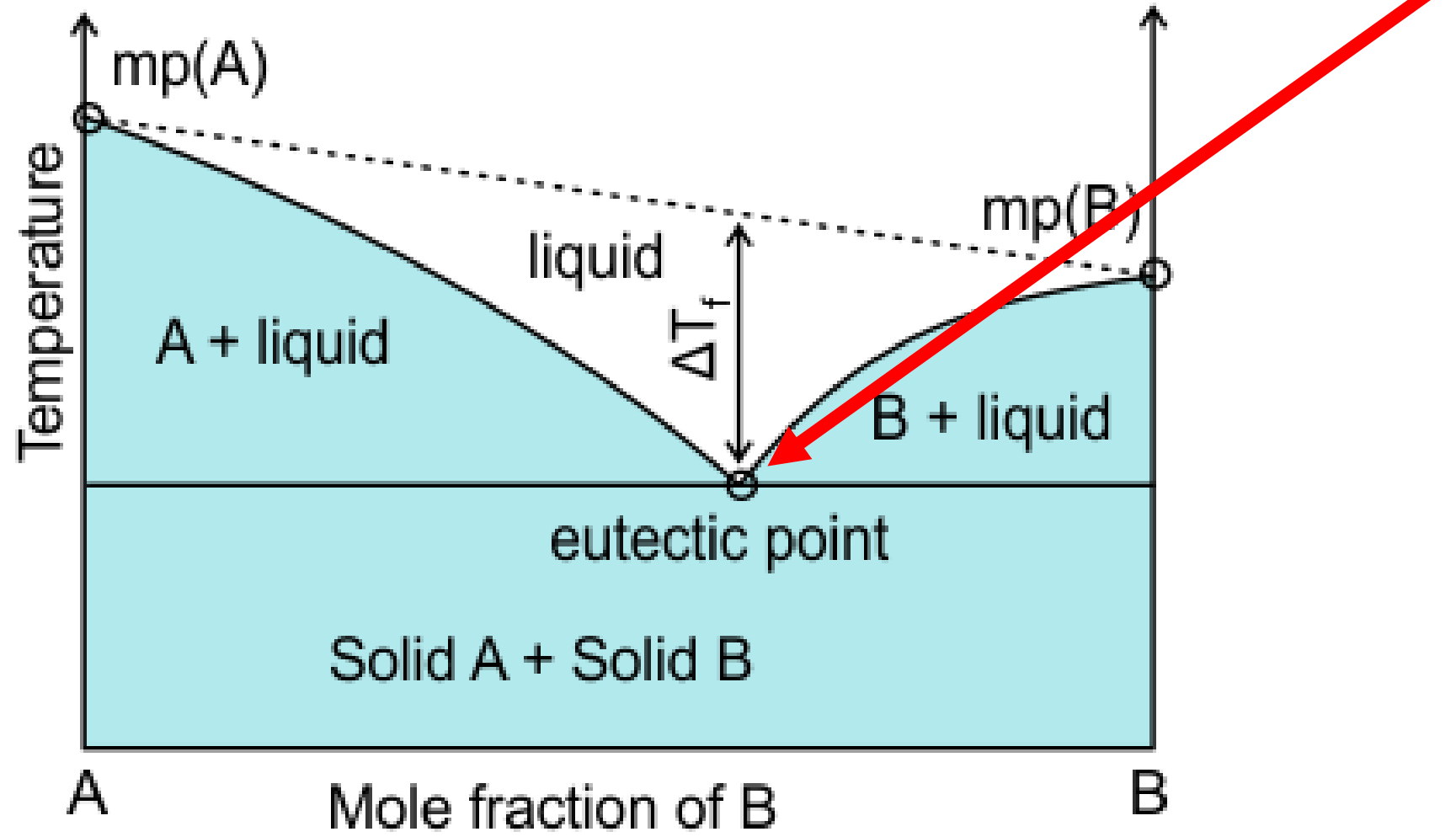
**Aluminum-Copper (Al-Cu) System:** Used to understand and design precipitation strengthening in alloys, a key process for making stronger aluminum materials.

**Lead-Tin (Pb-Sn) System:** Historically important for understanding soldering alloys and their eutectic points

# The Binary Eutectic Phase Diagram

A **binary eutectic phase diagram** shows the relationship between temperature, composition, and the stable phases present in a two-component system.

It is characterized by a specific composition, the **eutectic point**, which has the lowest possible melting temperature for any mixture of the two components.



# Iron - Iron Carbide (Fe-C) Diagram

is a graphical representation of the phases and microstructures that form in iron-carbon alloys as a function of temperature and carbon content.

**Importance:** The most important phase diagram in engineering. It governs the structure of all Steels (Carbon < 2.14%) and Cast Irons (Carbon > 2.14%)

# The Eutectoid Reaction in Steel

The eutectoid reaction describes the phase transformation of one solid into two different solids. In the Fe-C system, there is a eutectoid point at approximately 0.8 wt% C, 723°C. The phase just above the eutectoid temperature for plain carbon steels is known as austenite or gamma.

“Thank You”



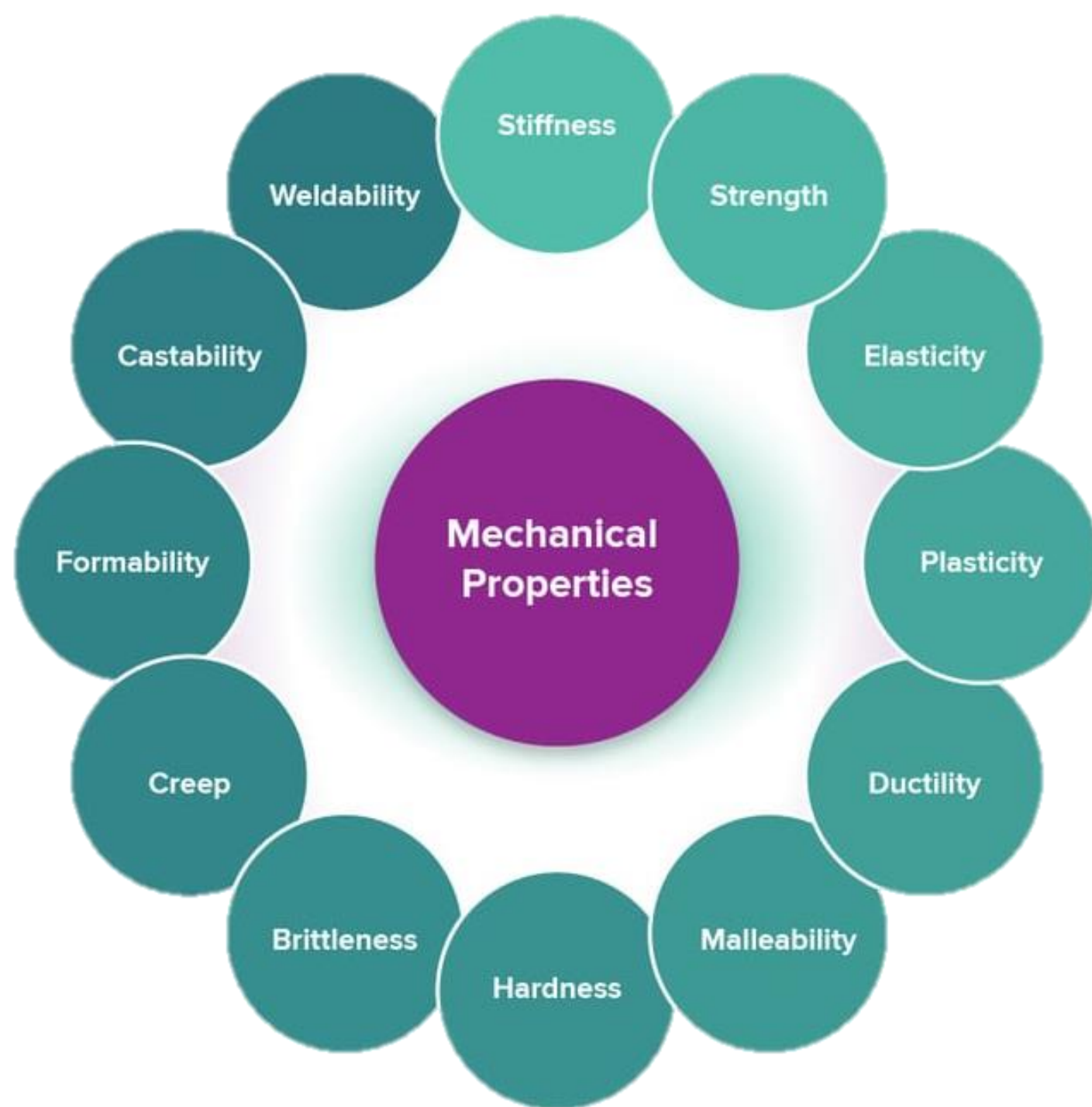
# **Mechanical Properties of Metals**

**Prof Dr. Mahir H. Majeed  
Al-Furat Al-Awsat Technical University  
College of Polytechnics/Karbala**

# Introduction to Mechanical Properties

**Definition:** Properties describing a material's behavior under an applied Load or Force (e.g., tension, compression, shear).

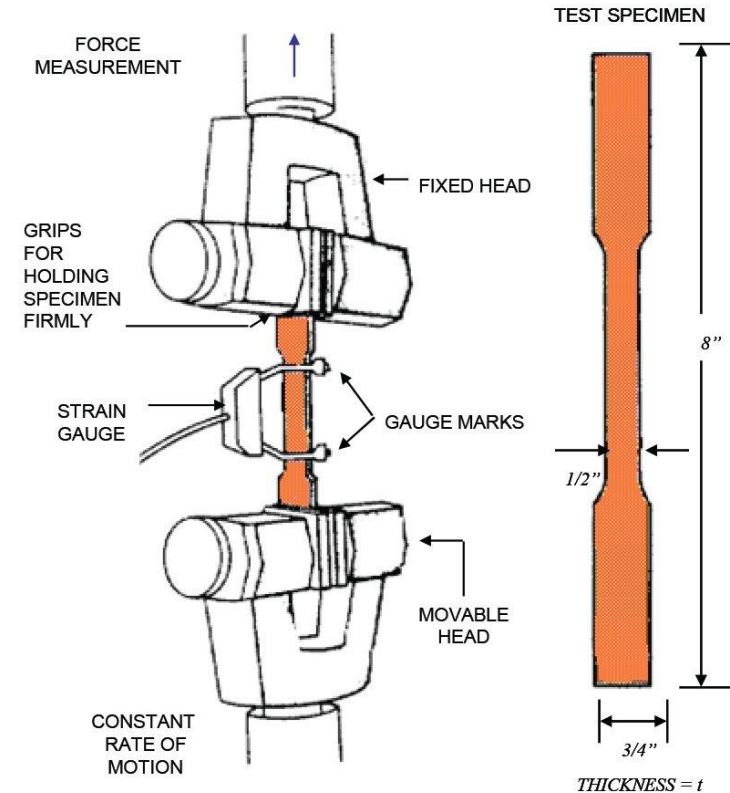
**Importance:** Critical for design and predicting material lifetime.



# The Tensile Test

The **Standard Tensile Test** is a fundamental mechanical test that provides critical information about a material's strength, stiffness, and ductility.

The results are typically presented in an **Engineering Stress-Strain Curve**.



# Procedure

- 1. Specimen Preparation:** A standardized "dog-bone" shaped specimen is prepared with specific dimensions (gage length and cross-sectional area). The reduced central portion ensures that the highest stresses occur in that area, localizing the deformation and eventual fracture there.
- 2. Mounting:** The ends of the specimen are securely clamped into the grips of the testing machine. An extensometer is often attached to the gage section to accurately measure the elongation.

# Procedure

**3. Loading:** A continuously increasing uniaxial tensile force (load) is applied to the specimen at a controlled rate until it fractures (breaks).

**4. Data Collection:** The applied load ( $F$ ) and the resulting change in length ( $\Delta L$ ) within the gage section are simultaneously recorded throughout the test.

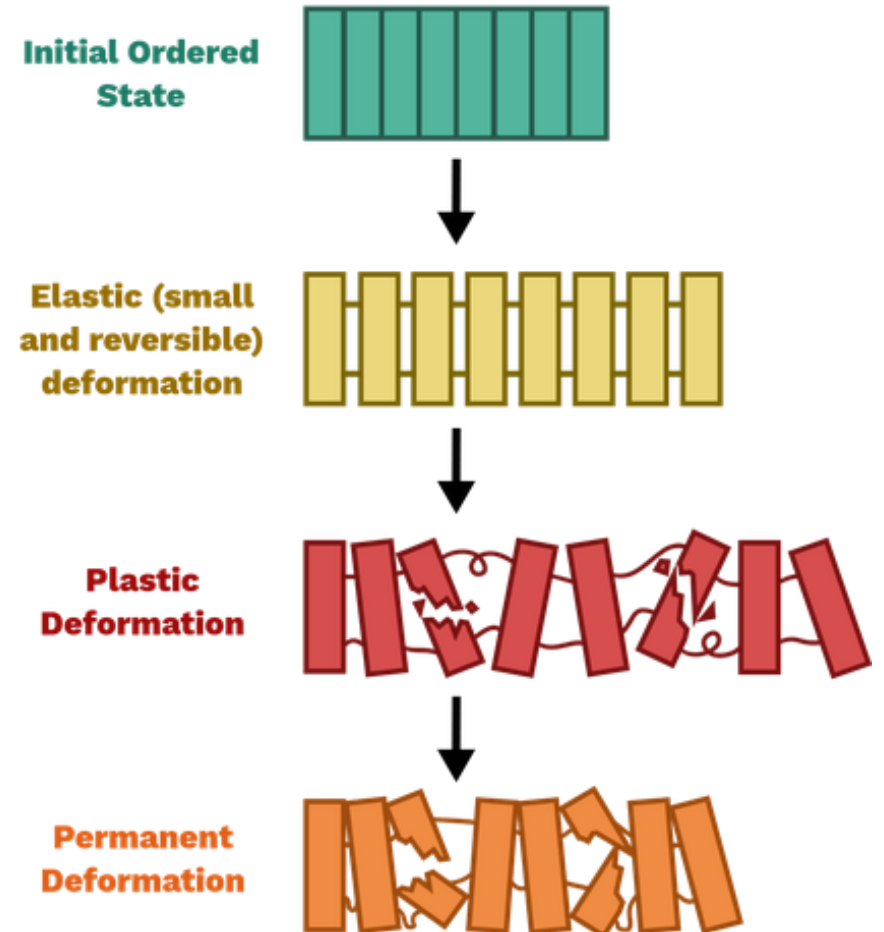
# Elastic vs. Plastic Behavior

## Elastic Deformation:

Reversible deformation; material returns to its original shape.

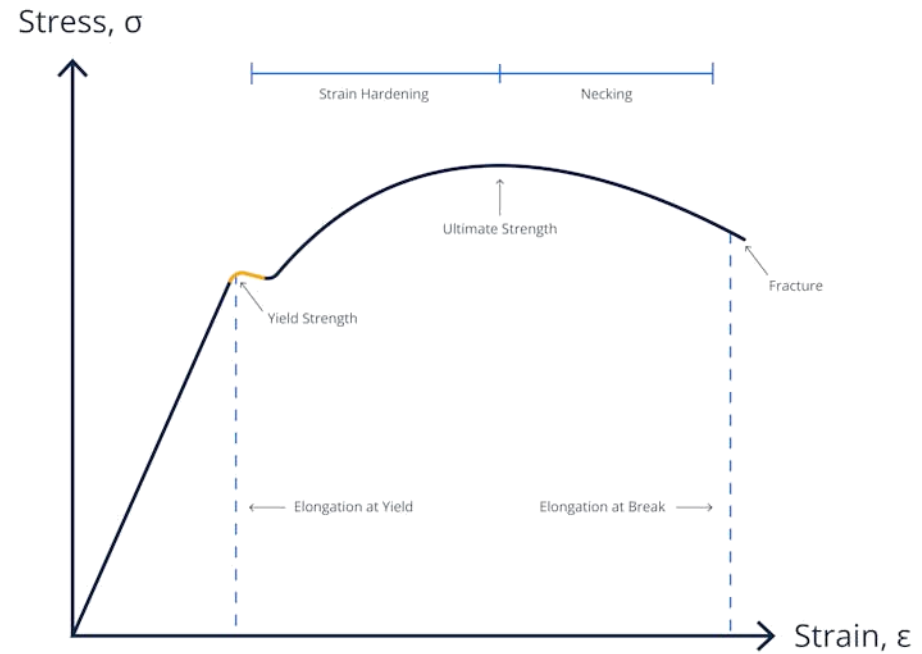
## Plastic Deformation:

Permanent deformation (related to dislocation motion).



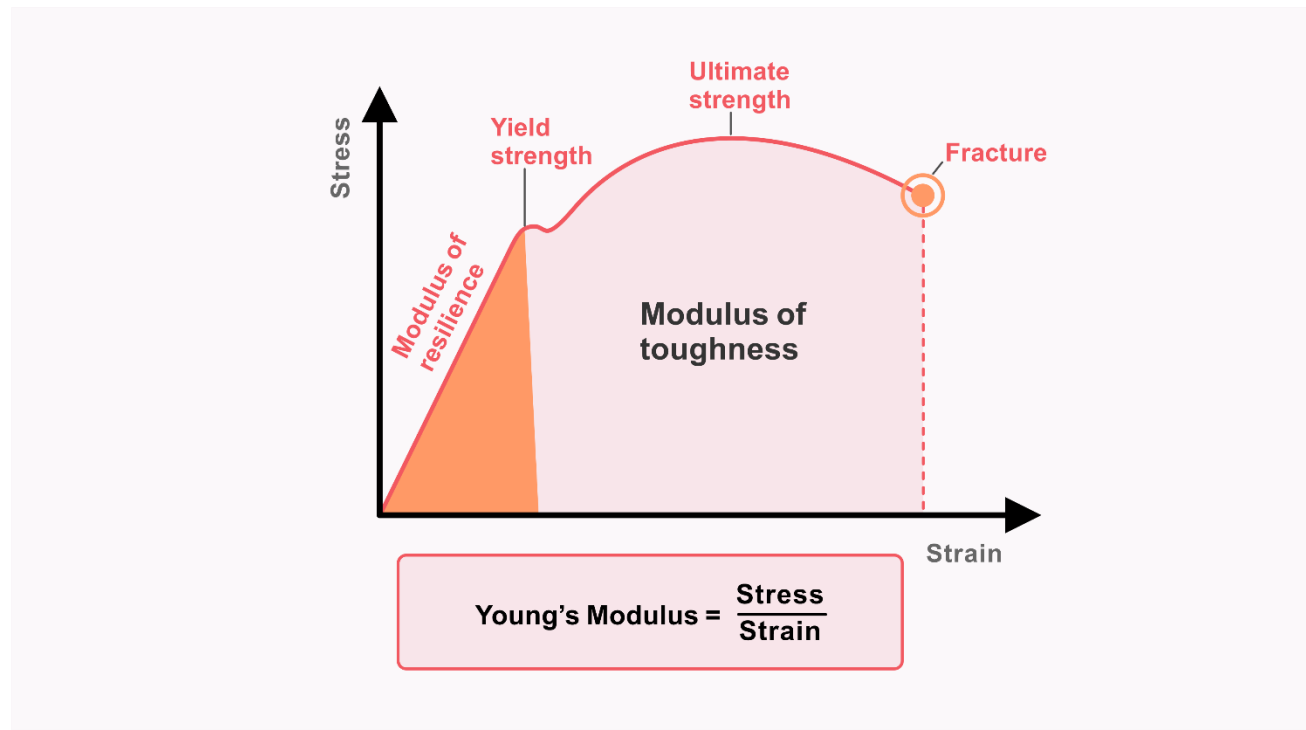
**Yield strength:** is the maximum stress a material can withstand before it starts to deform permanently (plastically), rather than just temporarily springing back (elastically).

Yield Strength Diagram



# Modulus of Elasticity

The **Modulus of Elasticity** is a fundamental material property that measures an object's **stiffness** or its resistance to being non-permanently (elastically) deformed under stress. It is defined as the ratio of stress to strain within the linear elastic region of a material's stress-strain curve.



# Strength, Hardness, Ductility and Brittleness

**Tensile Strength:** Maximum stress the material can endure.

**Hardness:** Resistance to plastic deformation, usually by indentation (e.g., Rockwell, Brinell tests)

**Ductility:** Material's ability to undergo plastic deformation before fracture (measured by %EL or %RA).

**Brittleness:** Material fractures with little or no plastic deformation (e.g., ceramics).

# Toughness and Resilience

**Resilience:** Material's ability to absorb energy in the Elastic range (area under the elastic curve).

**Toughness:** Material's ability to absorb energy up to Fracture (total area under the stress-strain curve)

# Mechanisms of Strengthening Metals

**Controlling Dislocation Motion:** Stress that causes plastic deformation is related to the stress needed to move dislocations.

**Strengthening methods:** Grain Size Reduction, Solid Solution Strengthening, and Strain Hardening (Cold Working).

# Strengthening mechanism

## Single - Phase material

Strain / Work Hardening

Grain Boundary Strengthening

Solid - Solution Strengthening

## Multi - Phase material

Precipitation Strengthening / age-hardening

Dispersion Hardening / 2nd Phase Hardening

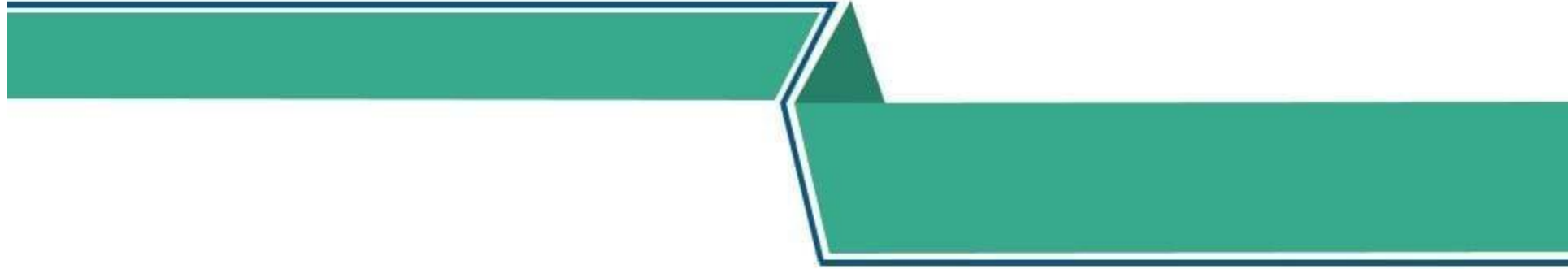
Martensitic hardening

# Fracture and Fatigue

**Fracture:** Separation of a material under stress (Ductile vs. Brittle fracture).

**Fatigue:** Failure under repeated or cyclic loading, even if the stress is below the yield strength.

“Thank You”



**First year**

**Polytechnic  
Karbala collage**

**Application on mechanical  
testing and properties**

**Lec.9**

**Dr. Zainab abdulraheem  
abdulhasan**

**Mechanical  
Engineering technical**

**Engineering Materials**

# 1. Creep

**Definition:** Time-dependent and permanent deformation of a material under constant stress at elevated temperature.

**Significance:** Undesirable phenomenon that often limits component lifetime.

**Metals:** Becomes significant at temperatures above  $\sim 0.4 T_m$  (absolute melting temperature).

**Polymers:** Amorphous polymers (plastics and rubbers) are highly sensitive to creep.

**Applications where creep is critical:** Turbine blades, boilers, reactors, engines, and high-pressure steam lines.

## CREEP CURVE

### 1. Stage I: Primary Creep

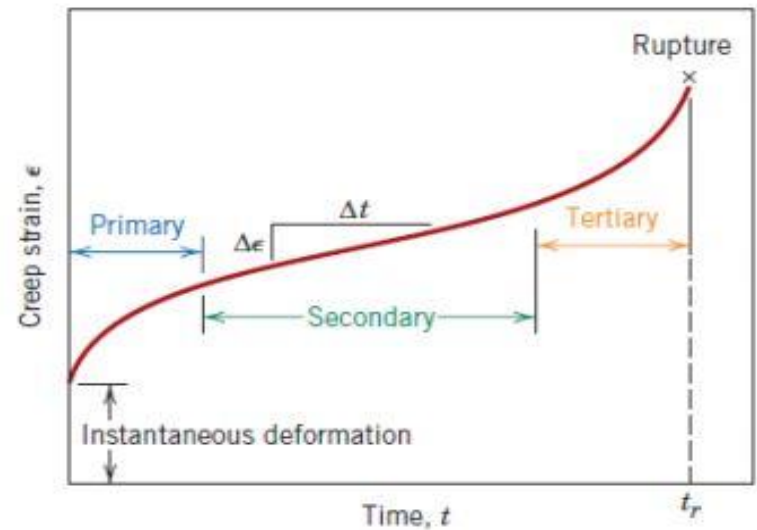
- Strain rate decreases as strain increases. Resistance to plastic deformation: strain hardening

### 2. Stage II: Secondary (steady-state) Creep (used as design tool)

- Strain rate minimum and constant  
Balance between recovery = strain hardening. Fracture will not occur.

### 3. Stage III: Tertiary Creep (failure-rupture)

- Strain rate increases. reduction in cross section al area due to voids, necking reduce



## 2. Impact Test

- Evaluates material behavior under **sudden and high loading rates**.
- Materials may behave more **brittle** compared to tensile testing.
- Used to determine **toughness**, i.e., the ability to absorb energy before fracture and particularly its capacity for resisting mechanical shock.
-

## Toughness

- Ability of a material to absorb energy and plastically deform without fracturing.
- Represented by the **area under the stress–strain curve**.
- Brittle materials → small area → low absorbed energy. (due to its limited toughness)
- Ductile materials → large area → high absorbed energy (increase toughness)

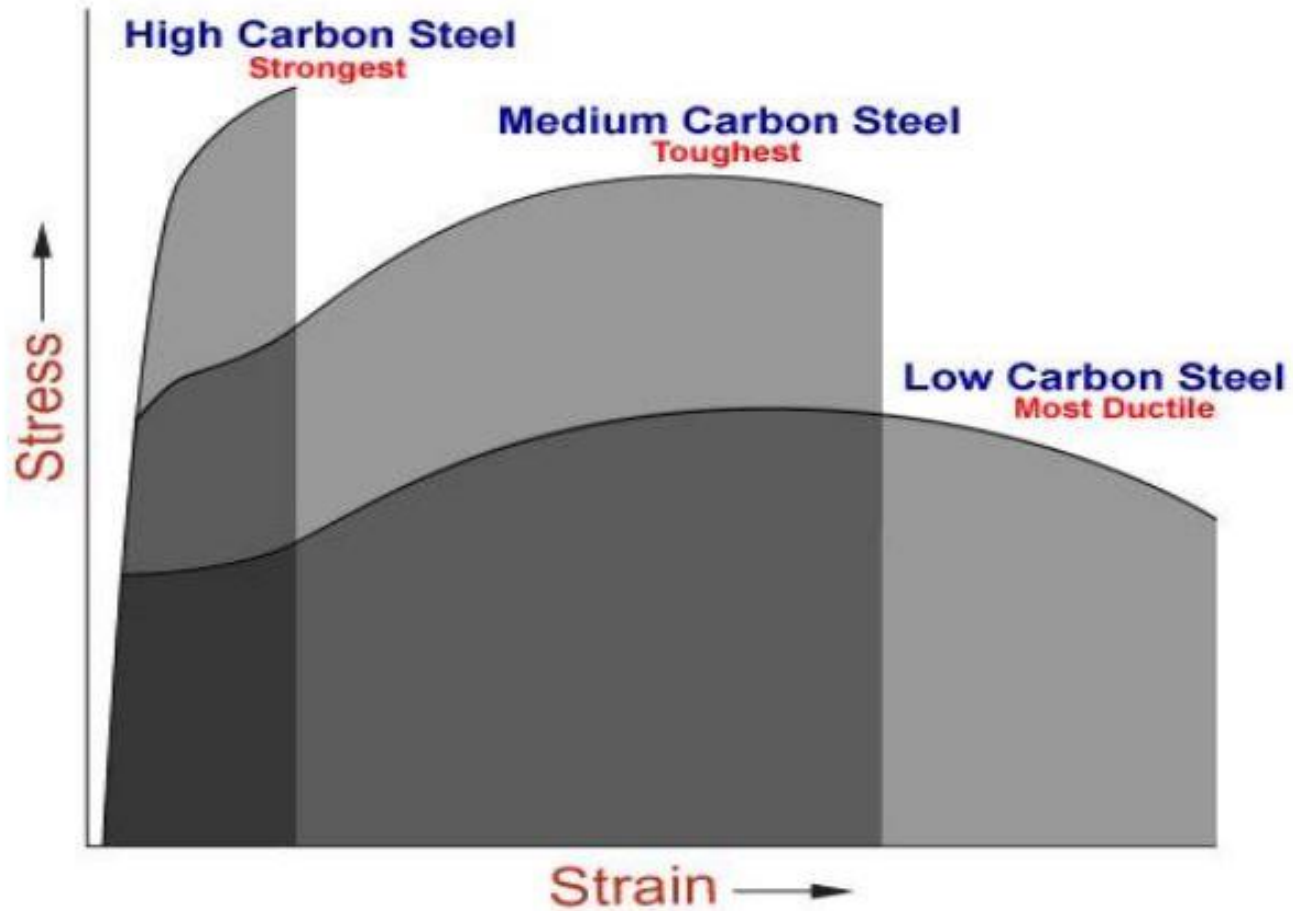


Figure 1: Toughness of Different Materials

# Types of Impact Tests

1. Charpy Test
2. Izod Test

Main difference: method of specimen support.

Impact energy is calculated by:

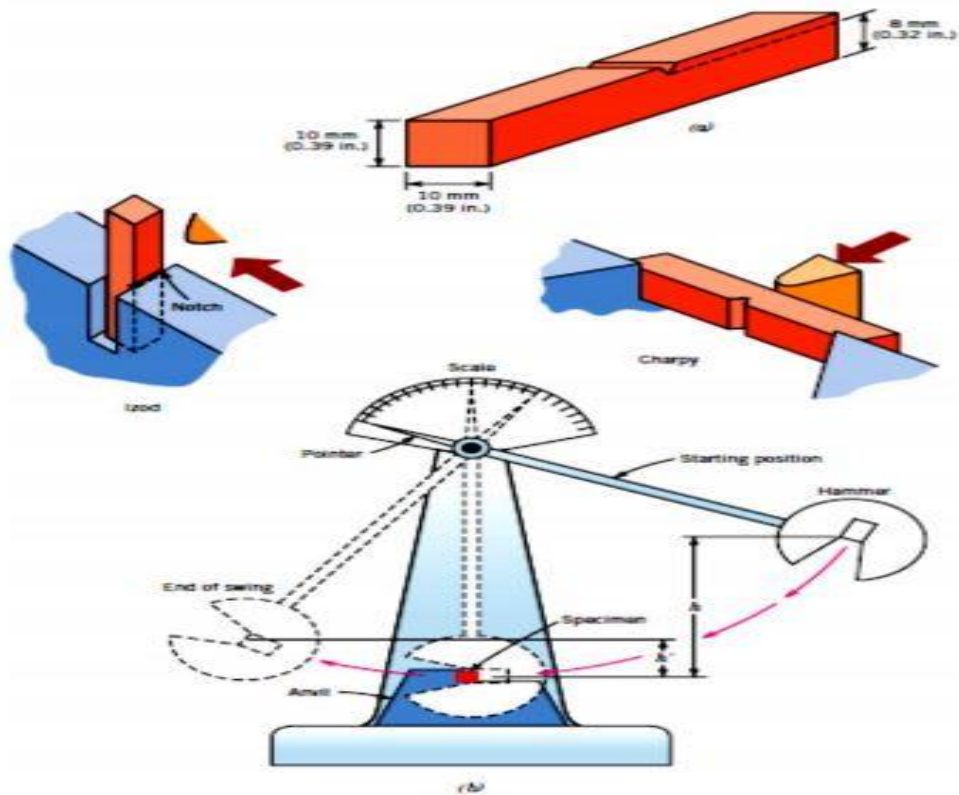
$$E = m g (h - h')$$

**Table 1: Differences between the Charpy and Izod techniques**

|                         | Izod Impact Test      | Charpy Impact Test |
|-------------------------|-----------------------|--------------------|
| Position of Specimen    | Vertical              | Horizontal         |
| Direction of Notch-Face | In front of striker   | Away from striker  |
| Type of Notch           | V-Notch               | V-Notch & U-Notch  |
| Striking Point          | Upper Tip of specimen | Centre of specimen |

Where  $m$  is the mass of pendulum and  $g$  is the gravitational acceleration.

The hammer is released from fixed height  $h$  and strikes the specimen; the energy expended in fracture is reflected in the difference between  $h$  and the swing height  $h'$ .



## Impact Strength

- Resistance of a material to fracture under dynamic loading.
- Defined as:
  - $K_c = K / S_0$

(where  $K$  is the work of the fracture and  $S_0$  is the cross-sectional area of the specimen at the notch).

It is defined as the specific work required to fracture a test specimen with a stress concentrator (notch) in the mid when broken by a single blow of striker in pendulum-type impact testing machine:

Impact strength is designated as KCU, KCV or KCT,

where the first two letters are the symbol of impact strength and the letter U, V or T indicates

the shape of the stress concentrator (notch):

U-shaped with the radius of the notch  $r_n = 1$  mm,

V-shaped with  $r_n = 0.25$  mm or

T-shaped notch with a fatigue crack at its tip

### 3. Fatigue

- Failure of a material under **cyclic or fluctuating stress**.
- Occurs at stress levels much lower than static fracture stress.
- Responsible for approximately **80% of engineering component failures**.
- Characterized by:
  1. Loss of strength
  2. Loss of ductility
  3. Sudden brittle fracture without warning( increased uncertainty in strength and service life.)

#### **Examples of Fatigue Loading**

Aircraft wings, leaf springs, connecting rods, rotating shafts, pumps, compressors, and turbines.

## **Factors Affecting Fatigue:**

Corrosion

Surface finish

Temperature

Microstructure

Heat treatment

Stress concentration

## **4. Mechanical Properties of Materials**

### **Elasticity**

Ability to regain original shape and size after unloading within elastic limit.

### **Plasticity**

Ability to undergo permanent deformation without fracture.  
Increases with temperature.

### **Ductility**

Ability of a material to be drawn into wires or elongated before fracture.

Measured by percentage elongation and reduction in area.

### **Strength**

Ability to withstand applied loads.

Types include tensile strength, elastic strength, and plastic (ultimate) strength.

## **Stiffness (Rigidity)**

Resistance to deformation, Measured by Young's modulus (E).

## **Malleability**

Ability to be hammered or rolled into thin sheets.,A compressive property.

## **Brittleness**

Tendency to fracture without significant plastic deformation.

Examples: glass, cast iron.

## **Toughness**

Ability to withstand shock and vibration.

Energy absorbed before fracture.

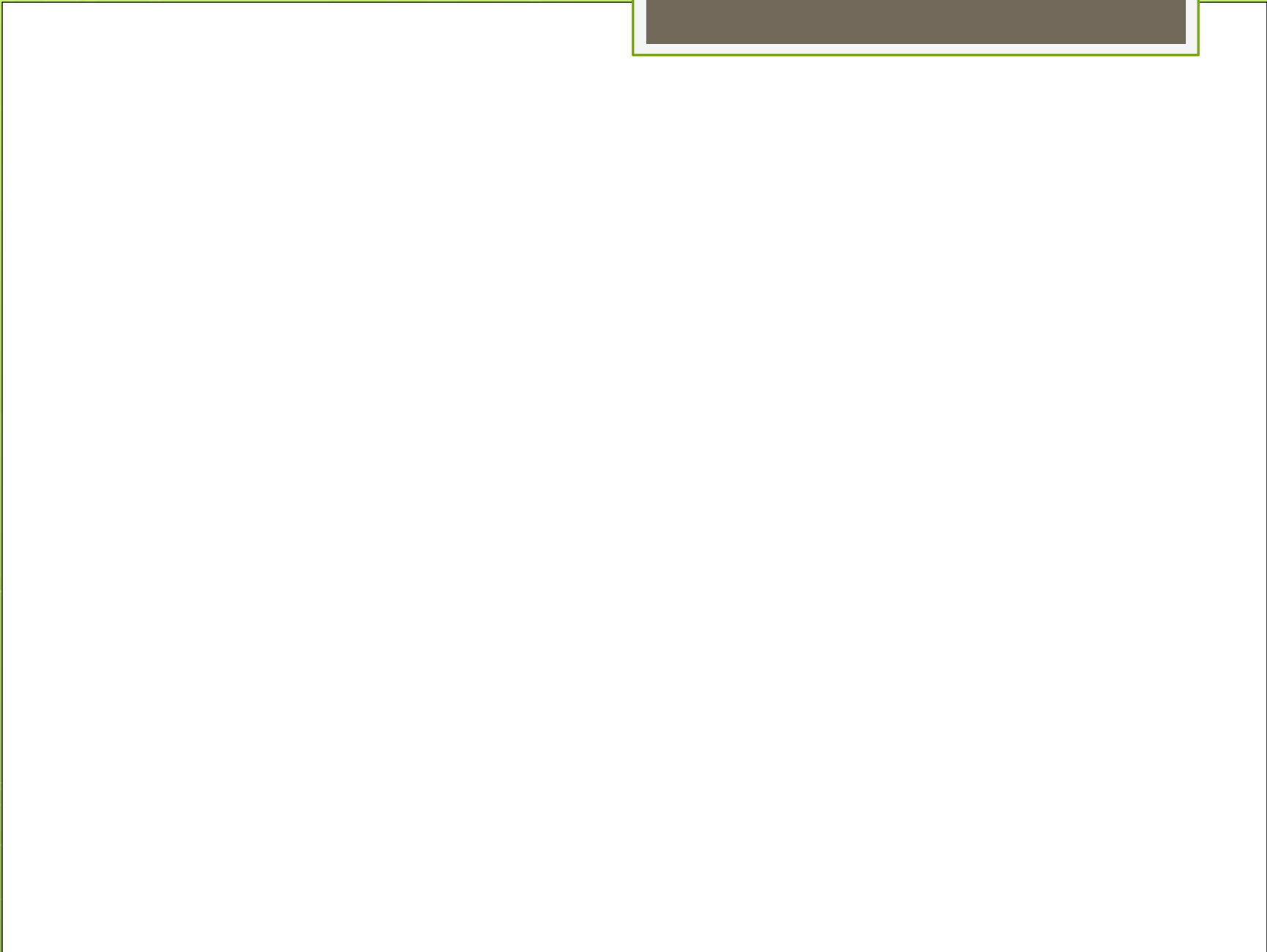
## **Tensile Toughness**

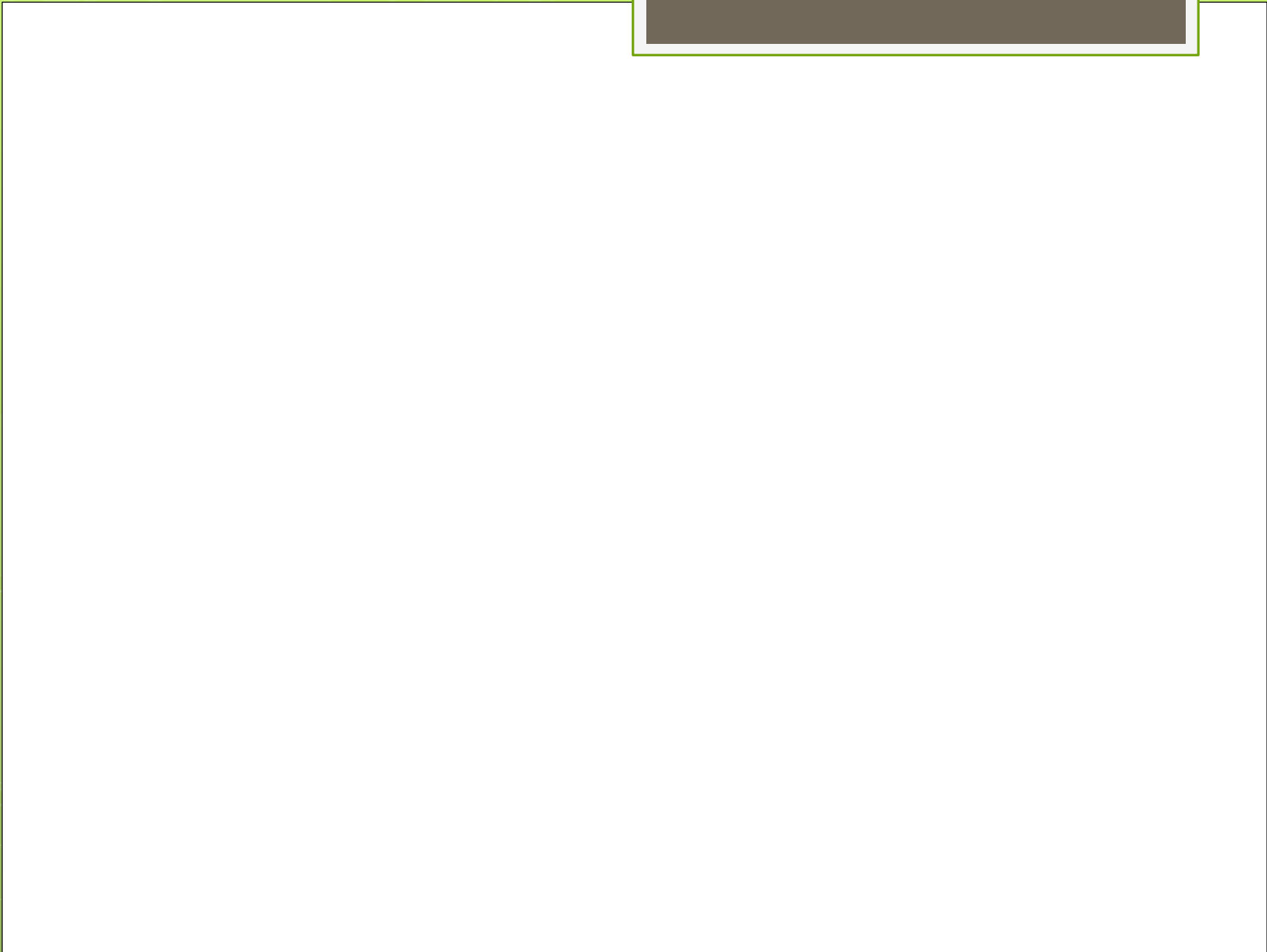
Energy absorbed up to fracture.

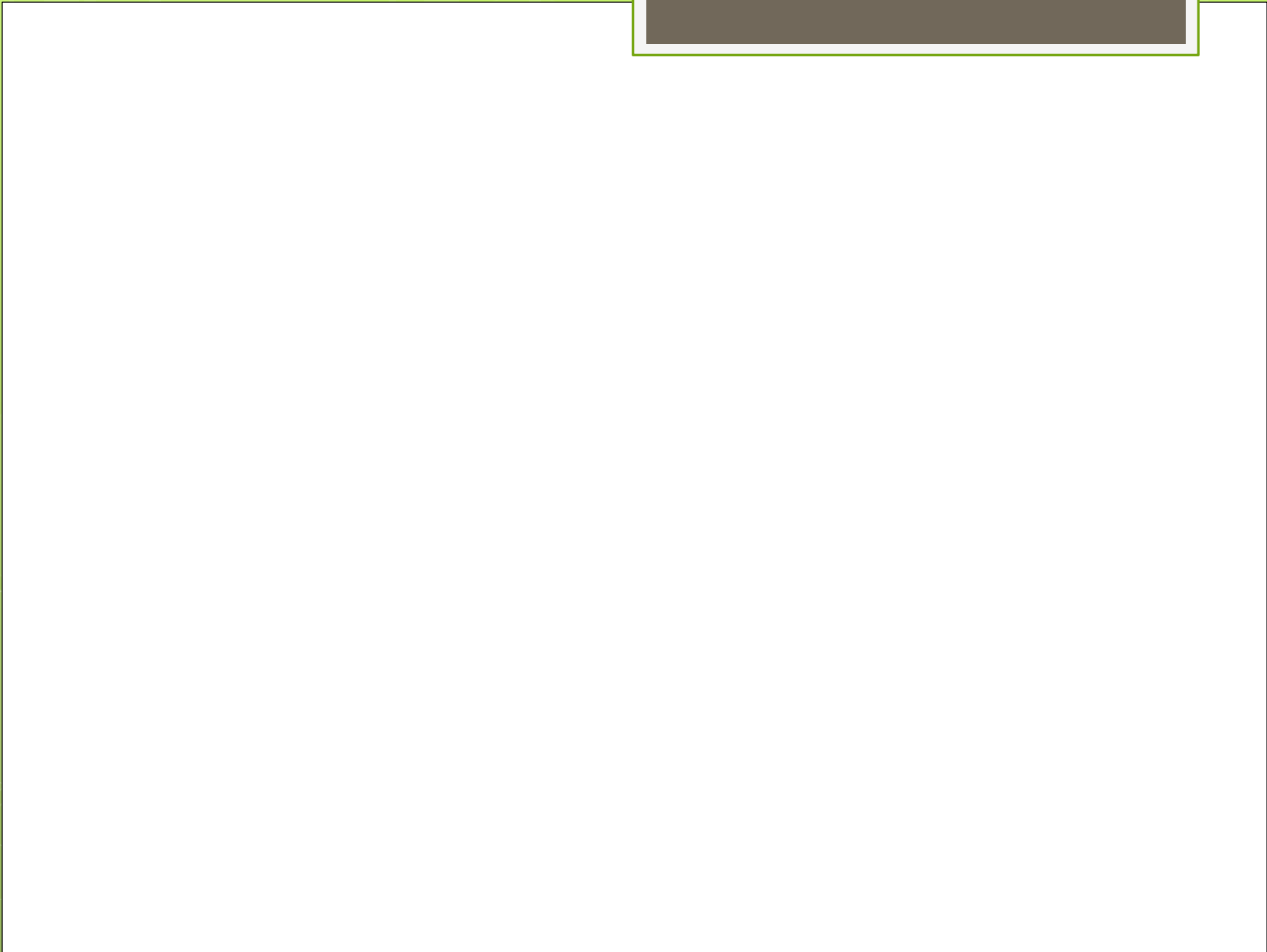
Equal to area under the stress–strain curve.

## **Resilience**

Ability to absorb elastic energy and release it upon unloading







**carbon exist as  
diamond, graphite,  
and  
amorphous carbon**

**Lec.10**

**Dr. Zainab abdulraheem  
abdulhasan**

**First year**

**Polytechnic  
Karbala collage**

**Mechanical  
Engineering technical**

**Engineering Materials**

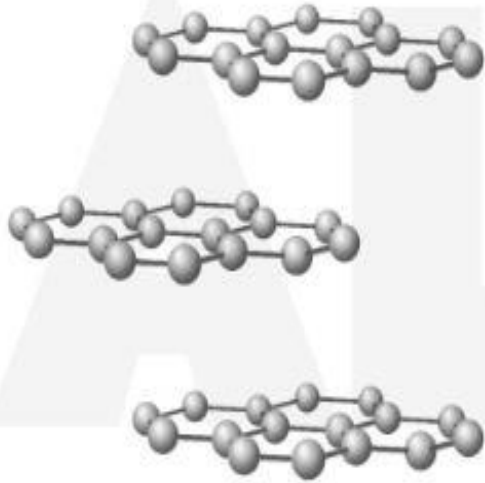
**carbon exist as diamond, graphite, and amorphous carbon**

The phenomenon by which an element can exist in more than one physical state is called **allotropy**. The allotropes of carbon can be categorized into two:

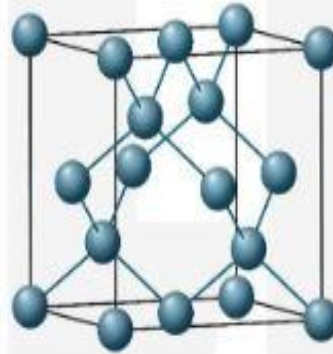
Amorphous Carbon Allotropes (Diamond,).

Crystalline Carbon Allotropes (Graphite)

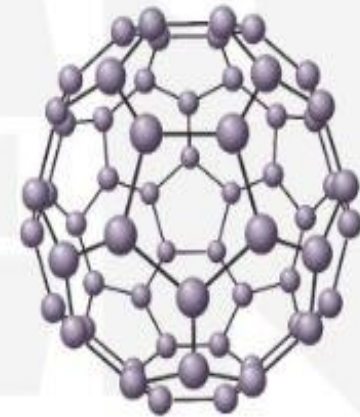
# CARBON ALLOTROPES



Graphite



Diamond



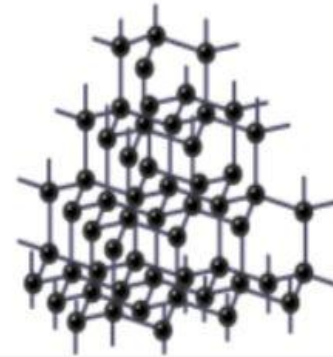
Fullerene

## Structure of Diamond

Diamond is a crystal formed under high-pressure, high-temperature conditions typically found deep within the Earth. The structure of diamond is a perfect tetrahedral lattice, where each carbon atom forms strong covalent bonds with four others, creating an incredibly stable and rigid network. This  $sp^3$  hybridization results in one of the densest and most durable crystal structures known.



Diamond



Diamond has a giant covalent structure in which:  
each carbon atom is joined to four other carbon atoms  
by covalent bonds  
the carbon atoms have a regular lattice arrangement  
there are no free electrons

Carbon atoms in diamond have a **tetrahedral (pyramid-shaped)** arrangement.

The hardness of the diamond is caused by the strong chemical binding of the carbon atoms among each other. The **specific diamond structure** is due to the carbon tetrahedral which is the smallest assembly alternately located in space.

## Physical Properties of Diamond

- has a very high melting point (almost 4000°C).
- Very strong carbon-carbon covalent bonds have to be broken throughout the structure before melting occurs.
- is very hard.

This is again due to the need to break very strong covalent bonds operating in 3-dimensions.

- doesn't conduct electricity.
- All the electrons are held tightly between the atoms, and aren't free to move.
- is insoluble in water and organic solvents.
- There are no possible attractions which could occur between solvent molecules and carbon atoms which could outweigh the attractions between the covalently bound carbon atoms

Jewelry, cutting tools,



## Applications of Diamond

## Structure of Graphite

Graphite's structure consists of layers of carbon atoms arranged in a hexagonal lattice. Each carbon atom is bonded to three others in the same plane, resulting in  $sp^2$  hybridization. These planes, or graphene sheets, are held together by weak van der Waals forces, allowing them to slide over one another easily



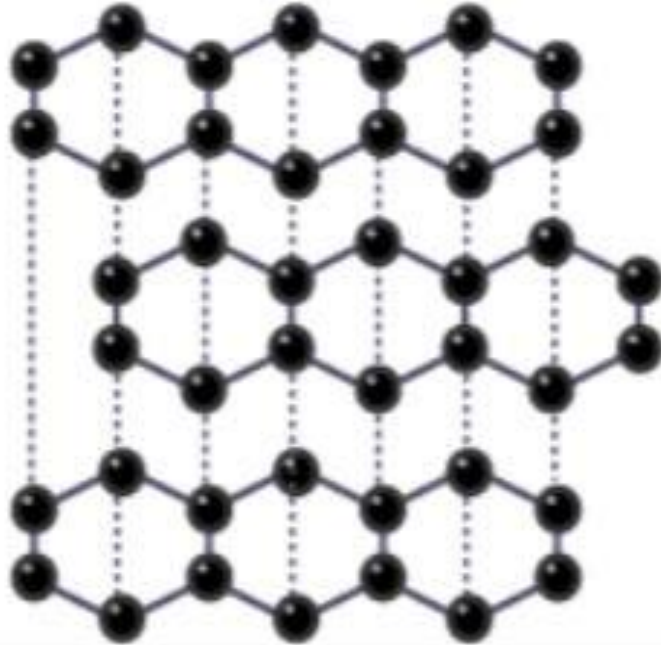
Graphite

## The Bonding in Graphite

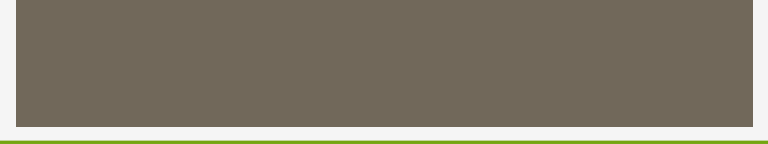
Each carbon atom uses three of its electrons to form simple bonds to its three close neighbors. That leaves a fourth electron in the bonding level. These "spare" electrons in each carbon atom become delocalized over the whole of the sheet of atoms in one layer. They are no longer associated directly with any particular atom or pair of atoms, but are free to wander throughout the whole sheet. The important thing is that the delocalized electrons are free to move anywhere within the sheet - each electron is no longer fixed to a particular carbon atom. There is, however, no direct contact between the delocalized electrons in one sheet and those in the neighboring sheets. The atoms within a sheet are held together by strong covalent bonds - stronger, in fact, than in diamond because of the additional bonding caused by the delocalized electrons.

## Important Properties and Applications of Graphite

- **Electrical Conductivity:** The delocalized electrons are free to move through the structure, in the graphene sheets allow for excellent conductivity along the plane of the layers.
- Lubricate Properties
- Thermal Resistance and Stability
- Electrodes
- Nuclear Reactors
- Pencil Leads
- Graphite has a lower density than diamond. This is because of the relatively large amount of space that is "wasted" between the sheets.
- Graphite is insoluble in water and organic solvents .



Dotted lines model the weak forces between the layers in graphite



| Property             | Diamond   | Graphite  |
|----------------------|---|---|
| Chemical Composition | Pure carbon   | Pure carbon   |
| Crystal Structure    | Tetrahedral, $sp^3$ hybridization, 3D crystal lattice | Layered, $sp^2$ hybridization, 2D planes with weak interlayer bonds               |
| Bond Type            | Strong covalent bonds (all directions)                | Strong covalent bonds (within layers), weak van der Waals forces (between layers) |
| Hardness             | Hardest known natural material (10 on Mohs scale)     | Soft, slippery (can be scratched easily)  |

|                         |  |  |
|-------------------------|--|--|
| Electrical Conductivity | Insulator (unless doped)                   | Good conductor due to free delocalized electrons in layers |
| Thermal Conductivity    | Very high (best natural conductor of heat) | High along the planes, low perpendicular to them           |
| Optical Properties      | Transparent, high refractive index         | Opaque, shiny metallic luster                              |
| Density                 | High density ( $3.51 \text{ g/cm}^3$ )     | Lower density ( $2.26 \text{ g/cm}^3$ )                    |

## **Amorphous Carbon Structure:**

Amorphous carbon lacks a crystalline structure. It is composed of carbon atoms in a random arrangement.

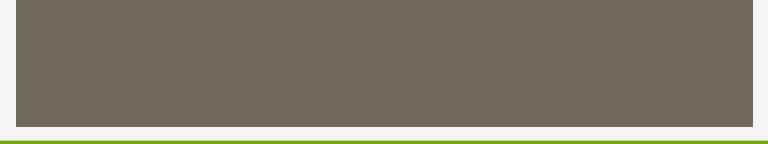
### **Examples of amorphous forms of carbon include:**

**Charcoal:** It is obtained by heating wood or other organic matter in the absence of air.

**Lamp Black (soot):** It is obtained by burning oily substances or hydrocarbons in limited supply of air. It is used in the manufacturing of printing inks and black paints.

**Animal Charcoal (bone black):** It is obtained by destructive distillation of bones. It is used in sugar refining industries for decolorizing sugar.

**Wood Charcoal:** It is obtained by the destructive distillation of wood. It is used as fuel and for making activated charcoal.



**Gas Carbon:** It is obtained by destructive distillation of coal. It is used in the manufacturing of electrodes.

**Activated Carbon:** It is obtained by heating wood or other forms of carbon in the absence of air to remove volatile components. It is used in gas masks for the absorption of poisonous gases.

**Sugar Charcoal:** It is obtained by heating sugar without air. It is used for decolorizing solutions.

Thus, amorphous forms of carbon are mainly by-products of various industrial and natural processes. These possess unique properties that have a wide range of practical applications.

# **Carbon Steel and Cast Iron**

**Prof. Dr. Mahir H. Majeed**

**Dr. Zainab abdulraheem abdulhasan**

**Al-Furat Al\_Awsat Technical University**

**College of Polytechnics/Karbala**

# Introduction to Iron Alloys

Most engineering metals are Iron-Carbon Alloys.

Iron alloys are metallic materials primarily composed of iron mixed with other elements (like carbon, chromium, nickel, silicon) to significantly enhance properties such as strength, hardness, corrosion resistance, and magnetism.

# Alloy Definition and Examples

An alloy is a mixture of chemical elements where the primary component is a metal.



## Bronze

copper (78-95%)  
tin (5-22%)



## 18K Gold

gold (75%)  
copper (12.5%)  
silver (12.5%)



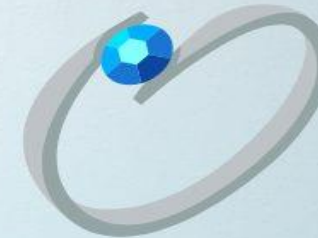
## Brass

copper (60-90%)  
zinc (10-35%)



## Cast Iron

iron (96-98%)  
carbon (2-4%)



## Sterling Silver

silver (92.5%)  
copper (7.5%)

# Carbon Steel: Classification by Carbon Content

## Types:

Classification based on weight percent Carbon:

- 1) Low-Carbon Steel ( $C < 0.25\%$ )
- 2) Medium-Carbon Steel ( $0.25\% < C < 0.6\%$ )
- 3) High-Carbon Steel ( $0.6\% < C < 1.4\%$ )

# Low-Carbon Steel

Properties: Soft, Ductile, easily weldable, low cost.

Uses: Sheet metal, structural components, automobiles body panels (where formability is key).

# Medium and High-Carbon Steel

Properties: Higher Strength and Hardness, less ductile, often requires heat treatment.

Uses (Medium): Railroad wheels, gears, shafts.

Uses (High): Springs, wires, high-strength cables.

# Types Of Carbon Steel

## Low Carbon Steel

Low carbon steel is the most common and cheapest type of Carbon Steel.



## High Carbon Steel

The hardest type has about 0.61 % carbon and is often used in the manufacture of brick nails and sharp cutting tools such as trencher blades.

## Medium Carbon Steel

This Medium Carbon Steel type has higher strength and less ductility than lower carbon types because of its carbon content of 0.31 % to 0.60 %. Gears and railroad lines contain medium carbons.



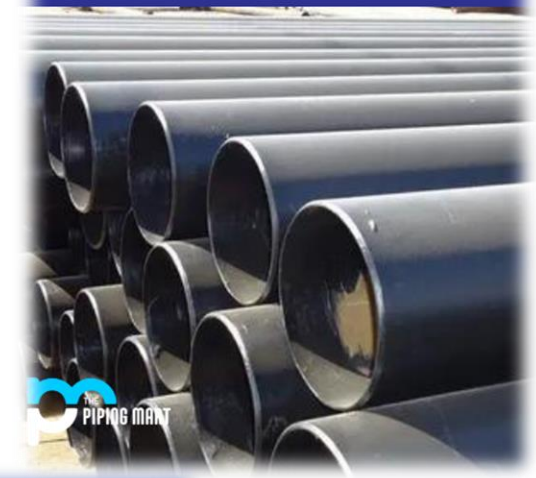
# Tool Carbon Steel

**Definition:** High-Carbon Steels often containing additional alloying elements (Cr, V, Mo) for enhanced properties.

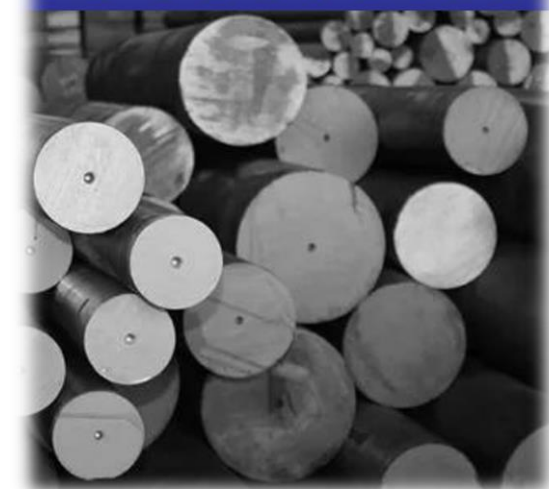
**Properties:** Excellent Hardness, high Wear Resistance, and ability to hold a sharp edge.

**Uses:** Dies, punches, cutting tools.

Carbon Steel



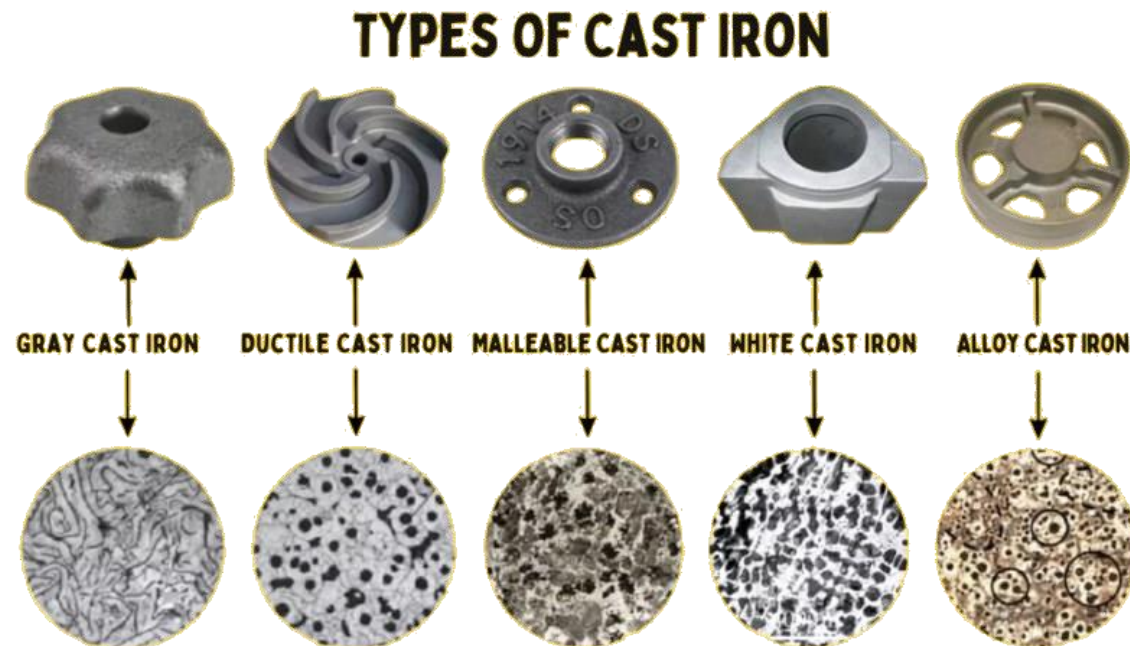
Vs Tool Steel



# Cast Iron

**Definition:** Iron alloys containing 2.14\% - 4.5\% Carbon.

**Key Feature:** Excellent castability (low melting point) and good damping capacity. Carbon is typically present as Graphite.

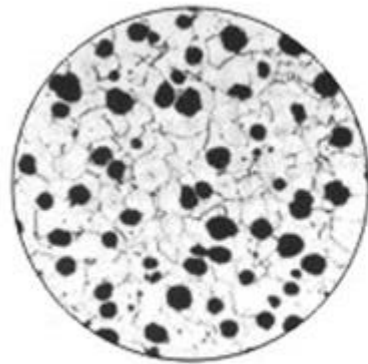


# Grey Cast Iron

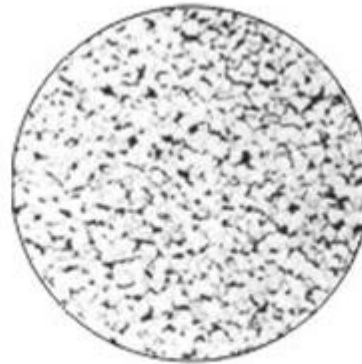
**Structure:** Carbon precipitates as Graphite Flakes.

**Properties:** Excellent vibration damping, good machinability, low cost.

**Uses:** Engine blocks, heavy machine bases, pipe fittings



Ductile Iron Pipes



Steel Pipes



Grey Iron Pipes

# White Cast Iron

**Structure:** Carbon exists entirely as Cementite ( $\text{Fe}_3\text{C}$ ).

**Properties:** Extremely Hard and highly Brittle (unmachinable).

**Uses:** Rollers, grinding mills, parts requiring high wear resistance (often used as an intermediate step).

# Ductile (Nodular) and Malleable Cast Iron

**Nodular/Ductile:** Graphite is in Spherical/Nodular form.

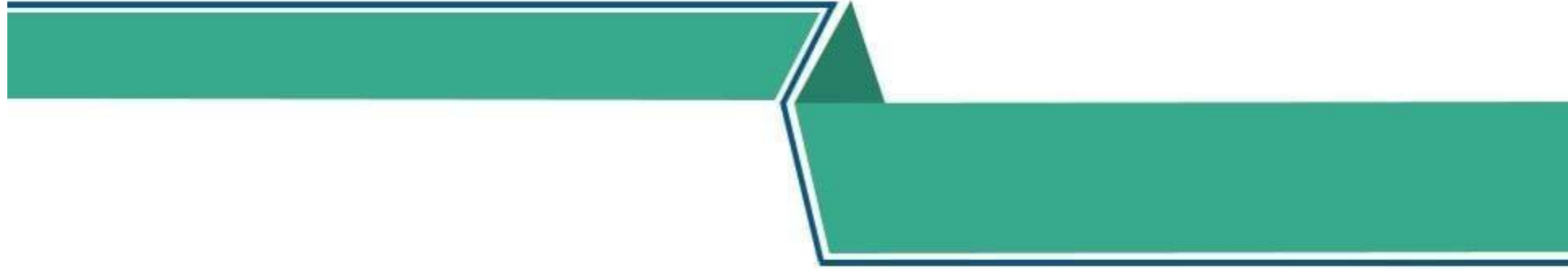
**Result:** Significantly improved Ductility and Toughness.

**Malleable:** Produced by heat-treating white cast iron; graphite forms Clusters.

**Result:** Good shock resistance.



“Thank You”



# Plastics

Lec.12

**Dr. Zainab abdulraheem  
abdulhasan**

**First year**

**Polytechnic  
Karbala collage**

**Mechanical  
Engineering technical**

**Engineering Materials**

# **Introduction to plastics technology**

Plastics technology is the science and engineering of plastic materials, covering their creation from raw petrochemicals or natural sources into versatile polymers, their processing into finished products, and their wide applications, focusing on material properties, design, and manufacturing techniques like molding and extrusion for everything from everyday items to complex industrial parts.

# Microstructure and polymerization

Plastics are commonly known as synthetic resins or polymers. In Greek terminology, the **term polymer** comprises ‘poly’ means ‘many’ and ‘mers’ means ‘parts’.

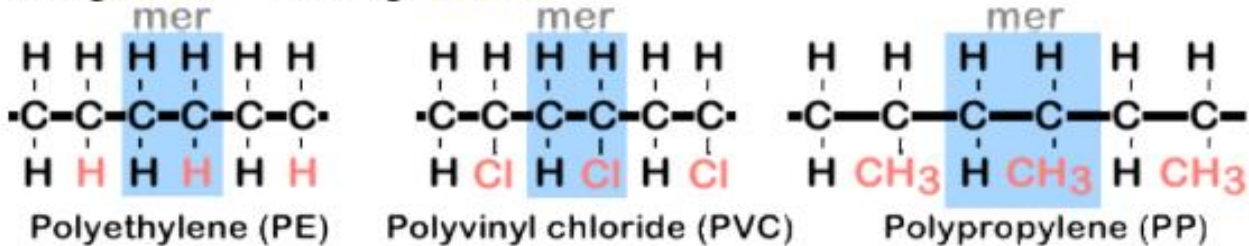
Thus, the term, polymer represents a substance built up of several repeating units, each unit being known as a **monomer**.

Thousands of such units or monomers join in a polymerization reaction to form a ‘**polymer**’.

# Microstructure and polymerization

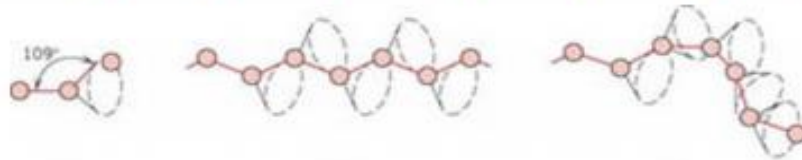
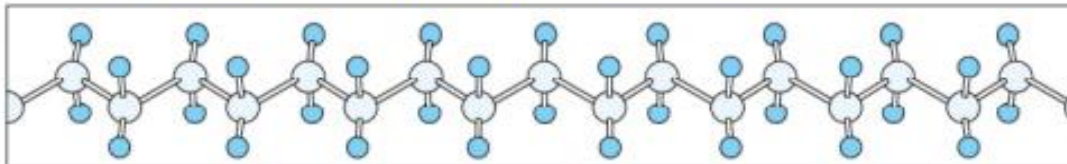
## Polymer Microstructure

- **Polymer** = many **mers**



Adapted from Fig. 14.2, Callister 6e.

## Polyethylene perspective of molecule



A zig-zag backbone structure with covalent bonds

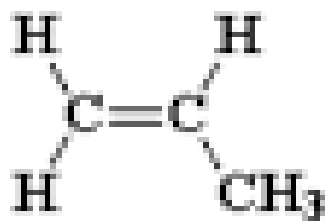
# Polymerization

“The process by which, monomer combine to form polymers is known as polymerization”.

**Degree of Polymerization (DP):** “The numbers of repeating unit present in it call degree of polymerization (DP)”.

- 1. Addition Polymerization :** When molecules just add on to form the polymer, the process is called ‘addition polymerization’ In ‘addition polymerization’ the molecular weight of the polymer is roughly equal, to that of all the molecules, which combine to form the polymer .Ex; Polyethylene, polypropylene

# Polymerization

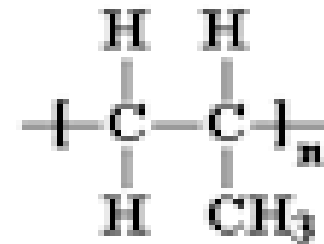


propylene

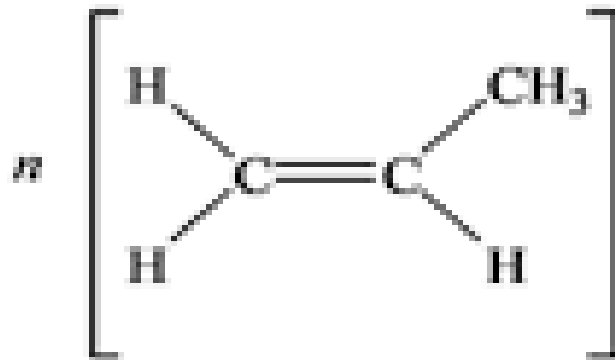
Ziegler-Natta  
polymerization



or metallocene  
catalysis



polypropylene



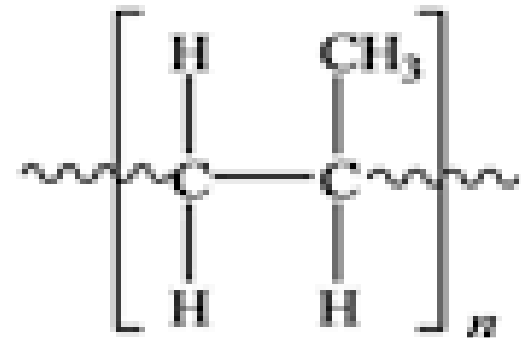
Propene  
(Monomer)

Catalyst

Heat



Pressure



Polypropylene  
(Polymer)

## 2. Condensation Polymerization:

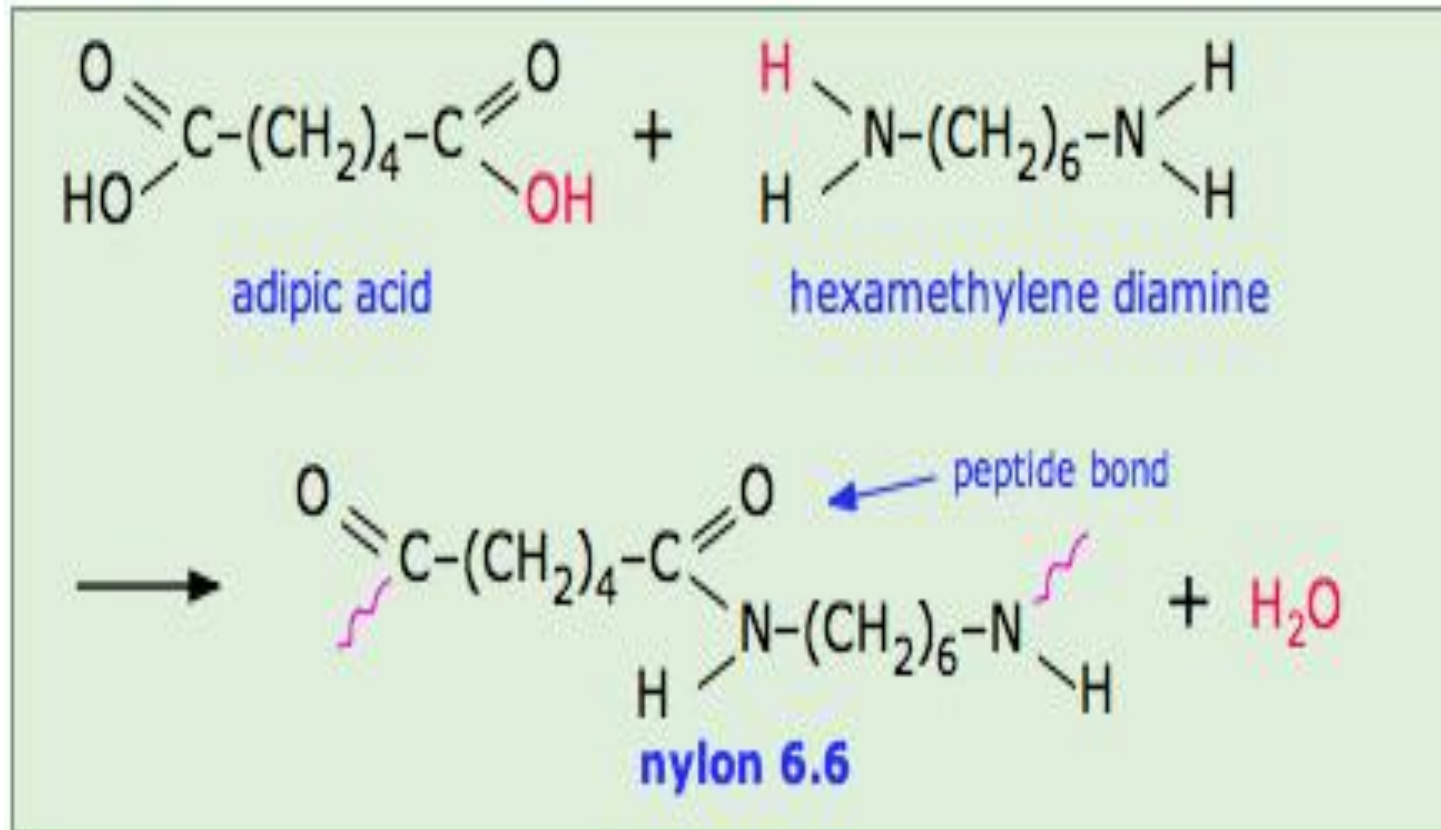
When, however, molecules do not just add on but also undergo some reaction in forming the polymer, the process is\_ called 'condensation polymerization'

The molecular weight of polymer is lesser by the weight of simple molecules eliminated during the condensation process\*

The condensation takes place between the two reactive functional groups, like the carbonyl group (of an acid) and hydroxyl group (of an alcohol) to form polyesters.

Ex. Nylon, PET

## Condensation Polymerization

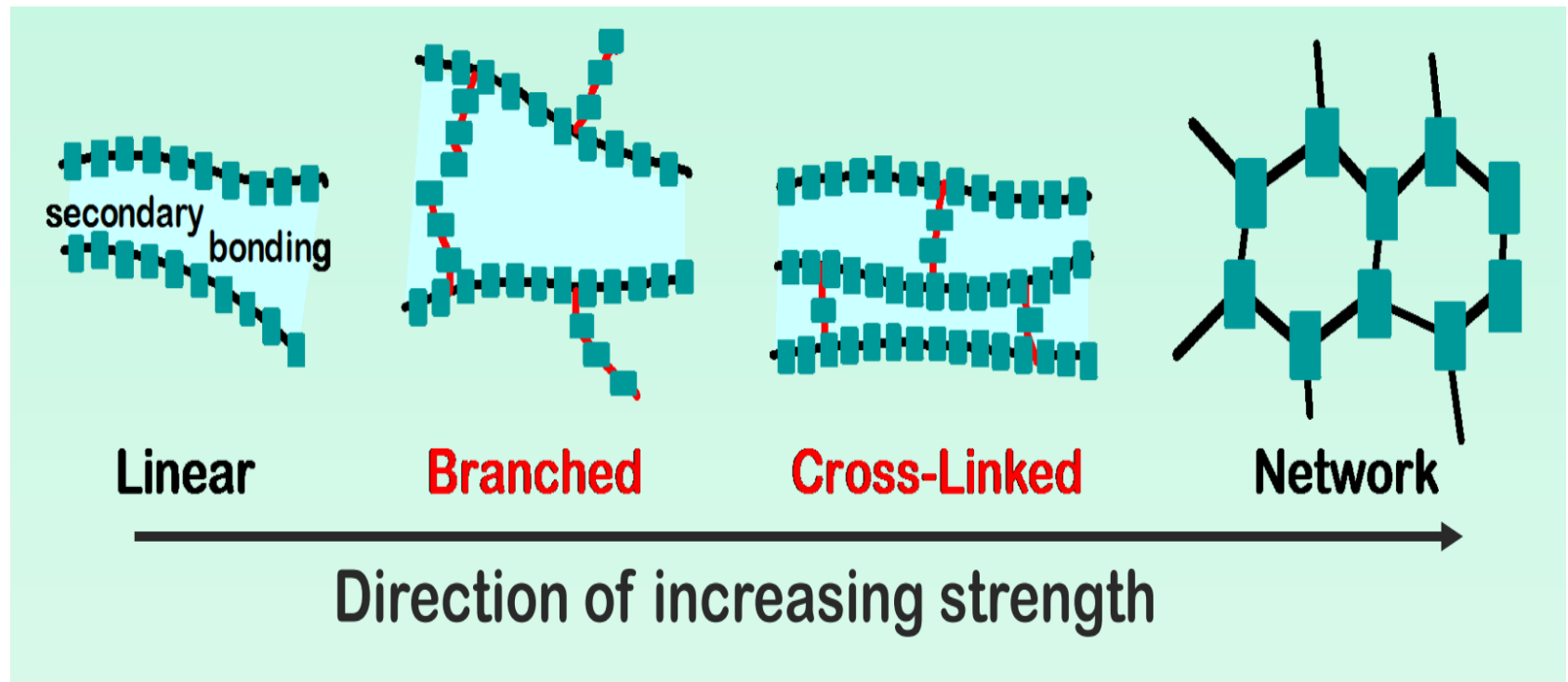


## Structure of plastics materials

polymer chains can be arranged in different ways :

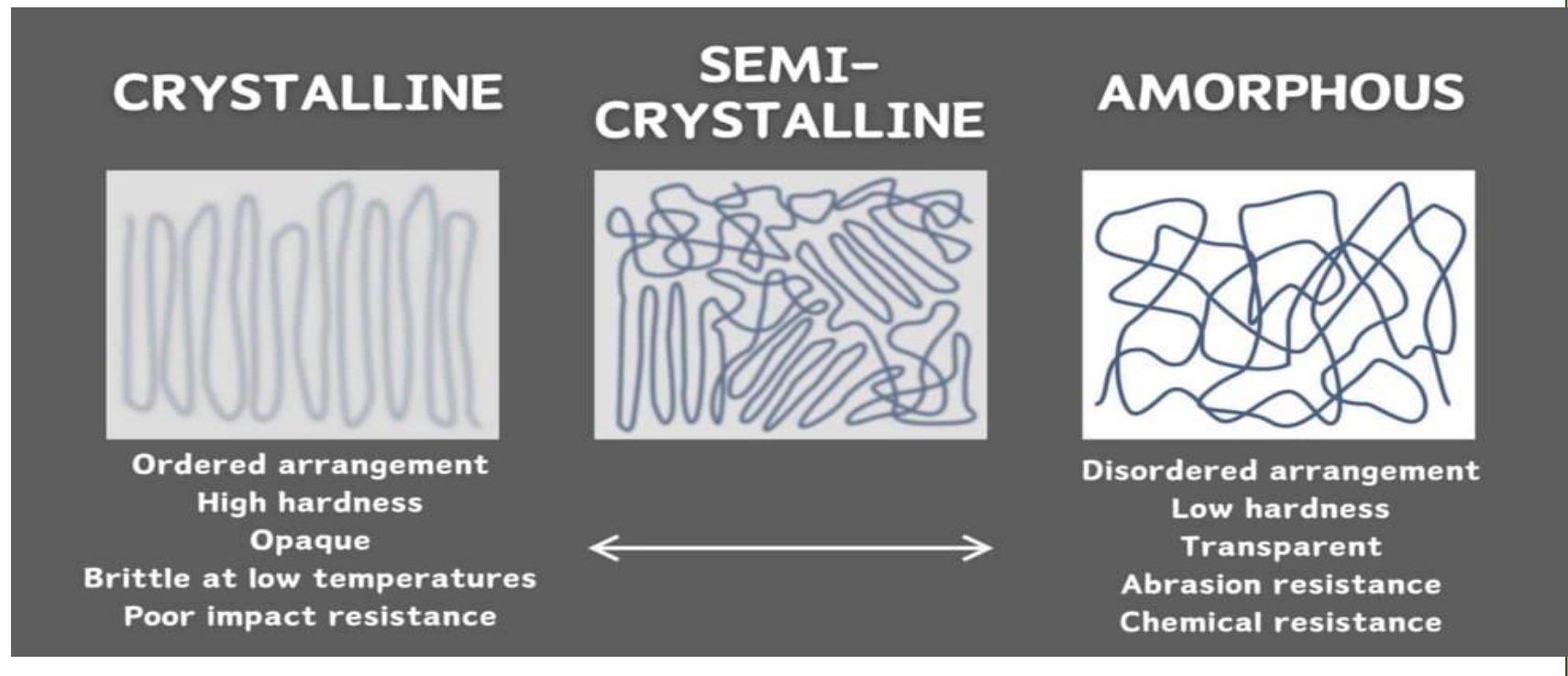
- **Linear:** Straight chains, often thermoplastic (soften on heating).
- **Branched:** Chains with side branches, affecting density and strength.
- **Crosslinked/Networked:** Chains linked together by covalent bonds, forming strong 3D networks, typical of thermosets (don't melt).

# Structure of plastics materials



## Molecular Order (Morphology)

- Amorphous: Disordered, random chain arrangement, leading to toughness and clarity (e.g., PVC, PS).
- Crystalline/Semi-crystalline: Orderly, tightly packed chains, providing stiffness, strength, and chemical resistance (e.g., PE, PP, Nylon).



## Classification of plastics

### Thermoplastics

- Polyolefin
- Vinyl chlorides
- Styroles & others

- PP Polypropylene
- PB Polybutylene
- PE polyethylene
  - LDPE
  - MDPE
  - HDPE

### Thermosets

- Thermo elastics
- Resins

### Elastomers

- Synthetic rubber



**Thermoplastics Polymers:** Thermoplastics are polymers that repeatedly soften when heated and harden when cooled.

**Thermosetting Polymers:** Thermosets are resins that undergo reaction during processing to become permanently insoluble and infusible due to they formed three-dimensional cross linked network structure when heat is applied.

**Elastomer:** Elastomers is a rubber-like material (natural or synthetic) that is generally identified as a material which at room temperature stretches under low stress to at least twice its length and snaps back to approximately its original length on release of the stress (pull) within a specified time period.

# Properties of plastics

The properties of plastics are given as under.

1. Plastics are light in weight and at the same time they possess good toughness strength and rigidity.
2. They are less brittle than glass, yet they can be made equally transparent and smooth.
3. They resist corrosion and the action of chemicals.
4. The ease with which they can be mass-produced contributes greatly to their popularity as wrappers and bags.
5. They can be easily molded to desired shapes.
6. They can easily be made colored.
7. They are hard, rigid and heat resistance.

# uses of plastics

Plastics are used in nearly every sector, primarily for packaging, construction, transportation, and electronics, due to their versatility, low cost, durability, and light weight, enabling applications from food containers and pipes to car parts, medical devices (implants, surgical tools), furniture, and electronic casings.



# **Ceramics and Glass**

**Prof. Dr. Mahir H. Majeed**

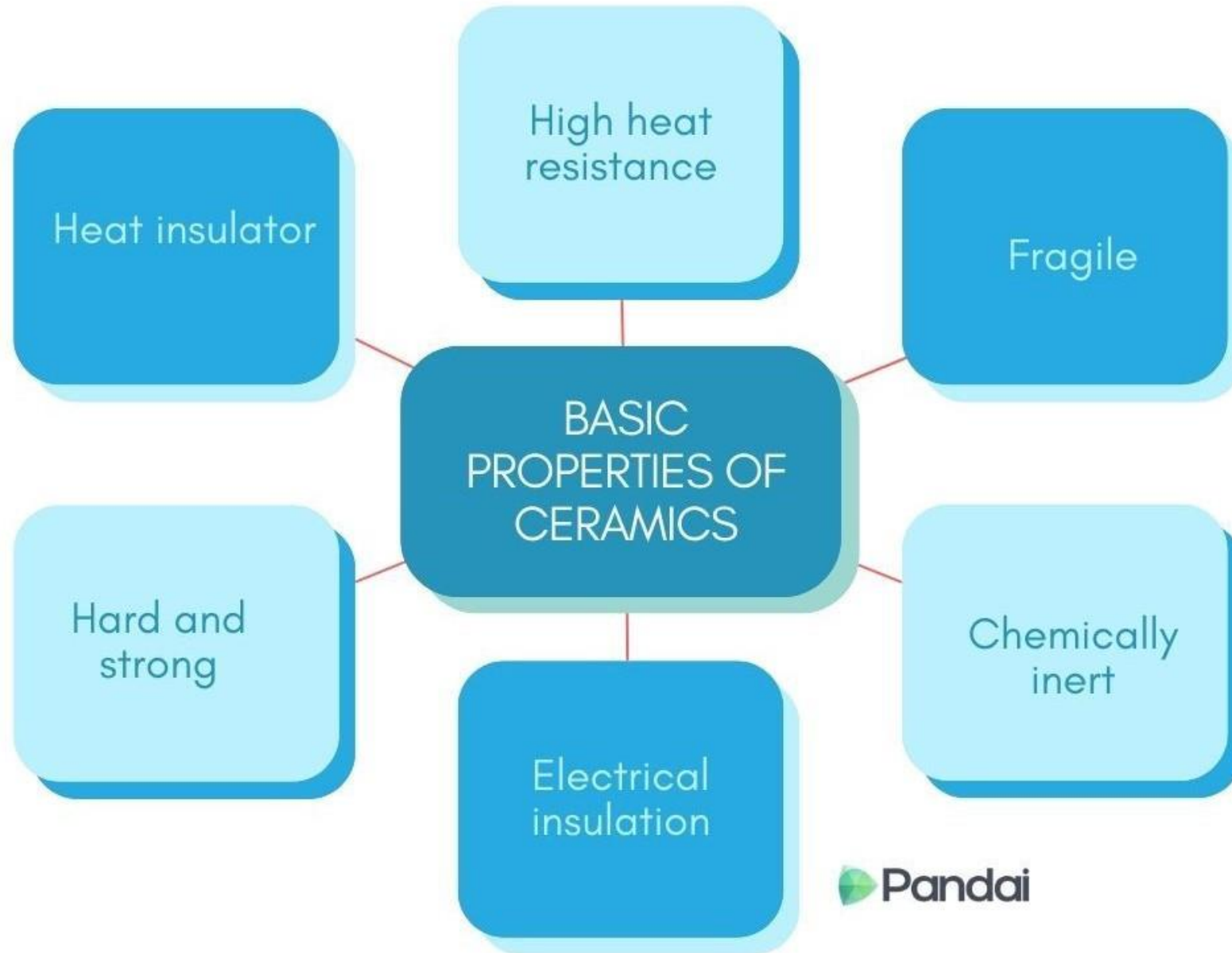
**Al-Furat Al\_Awsat Technical University**

**College of Polytechnics/Karbala**

# Introduction to Ceramics

**Definition:** Inorganic, non-metallic materials, typically compounds between metallic and non-metallic elements (e.g., Alumina, Silicon Carbide).

**Key Features:** High strength at high temperature, high hardness, resistance to corrosion.



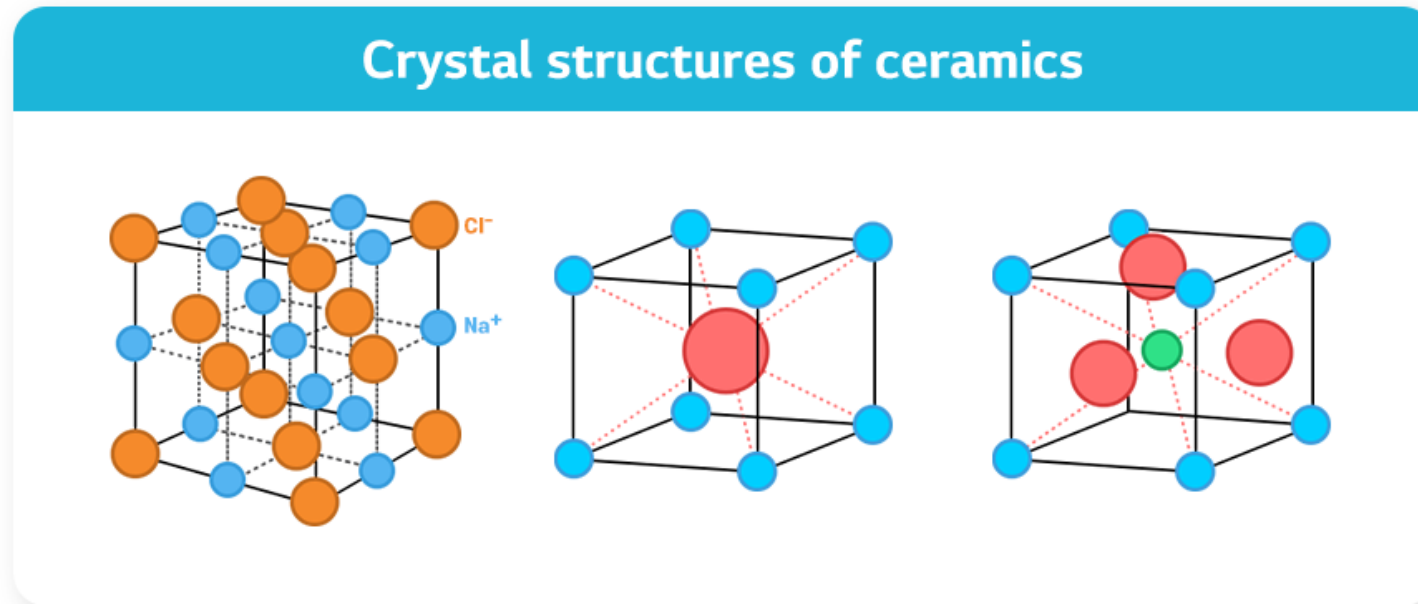
# Ceramic Structure: Ionic and Covalent Bonds

**Bonding:** Dominated by strong Ionic and/or highly Covalent bonds. This strong bonding dictates high melting points and stiffness.

**Structure:** Often crystalline, following rules of charge neutrality and ionic radii ratio.

# Crystal Structures in Ceramics

Ceramic crystal structures are complex, ordered arrangements of metallic cations and non-metallic anions, bonded ionically or covalently, that dictate their high hardness, brittleness, and insulating properties.



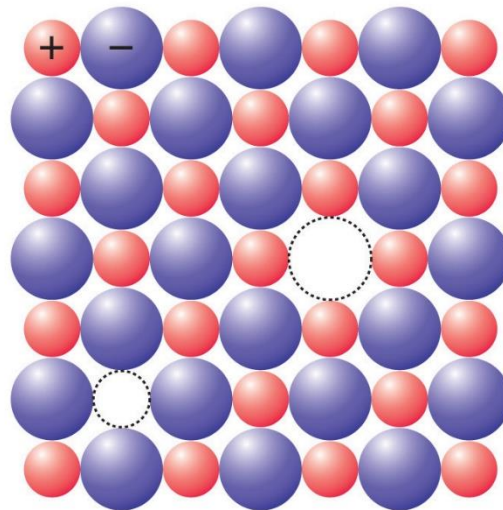
# Defects in Ceramics

Defects in ceramics are imperfections within the atomic structure (point, line, or planar) or macroscopic surface flaws (pinholes, cracks, warping) that significantly alter their physical, electrical, and mechanical properties.

They are primarily caused by atomic-level thermal excitation, impurities, improper firing, or cooling, often leading to reduced strength, brittleness, or discoloration.

# Schottky defect

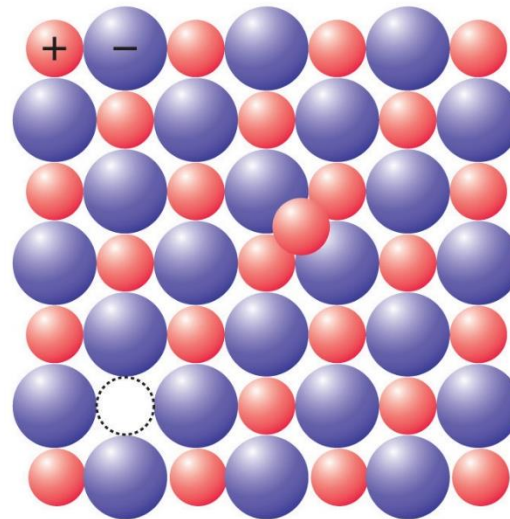
A Schottky defect is a type of point defect in ionic crystals where an equal number of cations and anions are missing from their lattice sites, creating vacancies while maintaining electrical neutrality. It reduces the crystal's density, increases ionic conductivity, and is common in compounds with similar-sized cations and anions, such as NaCl.



(a) Schottky defect

# Frenkel defect

A Frenkel defect is a type of stoichiometric point defect in crystalline solids where an atom or ion (usually a smaller cation) leaves its lattice site and occupies an interstitial position, creating a vacancy-interstitial pair. It maintains crystal electrical neutrality and density, occurring primarily in ionic solids with low coordination numbers and large cation/anion size differences.

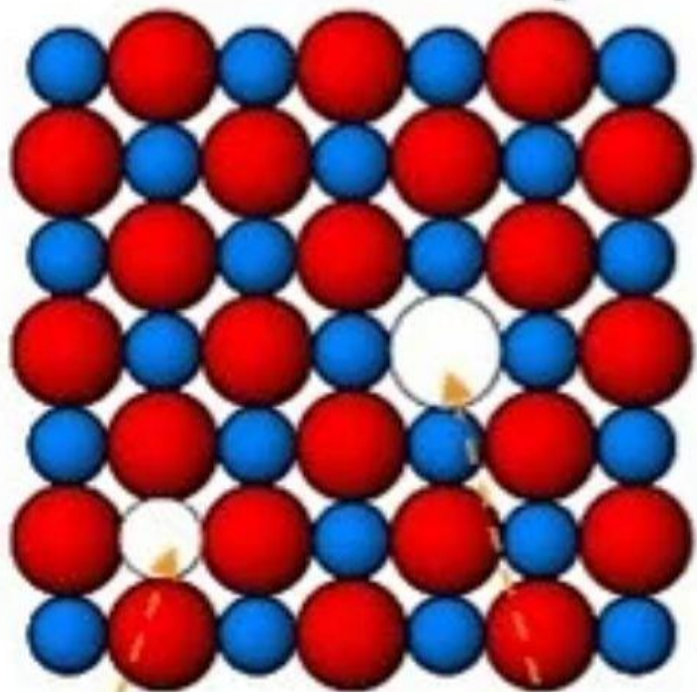


(b) Frenkel defect



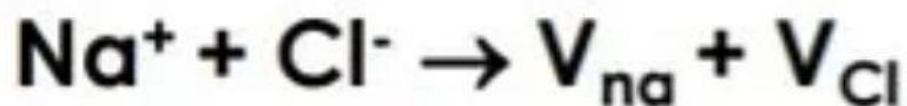
collegesearch

## Schottky

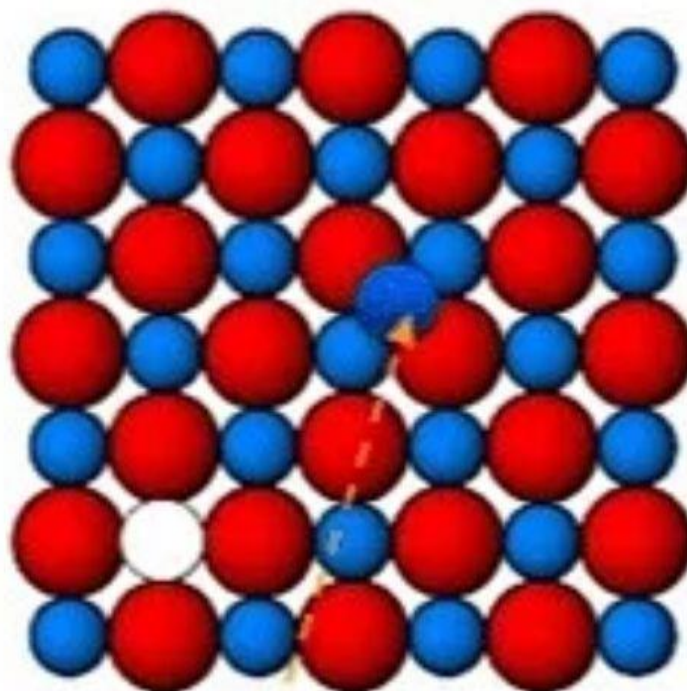


cation vacancy

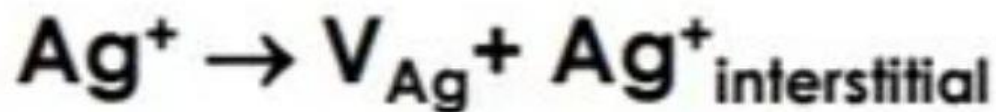
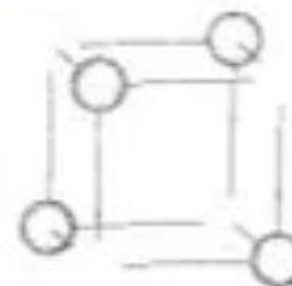
anion vacancy



## Frenkel



interstitial cation



# Properties of Crystalline Ceramics

**Mechanical Properties:** High compressive strength, high hardness, high elastic modulus (stiffness), and, most notably, high brittleness (low ductility). They have low tensile strength and poor impact strength.

**Thermal Properties:** High melting points and excellent heat resistance (refractory), making them suitable for high-temperature applications like furnace linings. They typically have low thermal expansion coefficients and low thermal conductivity.

**Electrical Properties:** Generally excellent electrical insulators, although some specialized compounds can be semiconducting or superconducting.

**Chemical Properties:** High chemical inertness, high resistance to oxidation, and high stability in harsh environments.

**Structure:** Ordered, periodic atomic arrangement.

**Optical Properties:** Typically opaque or translucent due to light scattering at grain boundaries in polycrystalline structures, though single-crystal ceramics (like sapphire) can be transparent.

# Uses of Crystalline Ceramics

**Electronics & Semiconductors:** Due to their electrical insulating properties and thermal stability, they are used in semiconductor devices, microchips, and circuit boards. Piezoelectric crystals are also used as sensors, actuators, and in quartz watches.

**Aerospace & Defense:** Used in turbine blades, heat shields, and armor-piercing ammunition because of their ability to withstand extreme temperatures and mechanical stress.

**Medical & Dental:** Biocompatible, wear-resistant materials like alumina and zirconia are used for artificial joints and dental implants.

**Industrial & Energy:** Used in high-temperature environments (furnace linings), as cutting tools (abrasives), and in solid oxide fuel cells (SOFCs) for energy conversion.

**Optics & Specialized Tools:** Sapphire and YAG (yttrium aluminum garnet) are utilized in lasers, high-power lenses, and windows for harsh environments.

**Fireproofing:** Ceramic fibers are used in safety equipment and protective clothing.

# Introduction to Glass (Non-Crystalline Ceramics)

Glass is an amorphous, non-crystalline solid material, often classified as an inorganic ceramic, defined by its disordered atomic structure rather than a regular, periodic crystal lattice. Unlike conventional ceramics, it forms a supercooled liquid that lacks long-range order, giving it distinct properties such as high transparency, chemical inertness, and brittleness.

**Properties:** Glasses exhibit excellent hardness, chemical resistance, and, depending on composition, transparency.

# Types and Uses of Glasses

- 1. Fused Silica Glass (Vitreous Silica)**
- 2. Soda-Lime Glass**
- 3. Borosilicate Glass (e.g., Pyrex, Duran)**
- 4. Lead-Oxide Glass (Lead Crystal)**
- 5. Aluminosilicate Glass**

## **Fused Silica Glass (Vitreous Silica)**

**Uses:** Used in high-temperature applications such as furnace tubes and melting crucibles, as well as in optical fibers and astronomical telescopes.

## **Soda-Lime Glass**

**Uses:** Accounts for over 75% of manufactured glass, commonly used for windows, bottles, jars, and general consumer tableware.

## **Borosilicate Glass**

**Uses:** Widely used for laboratory glassware, household cookware, and car headlamps.

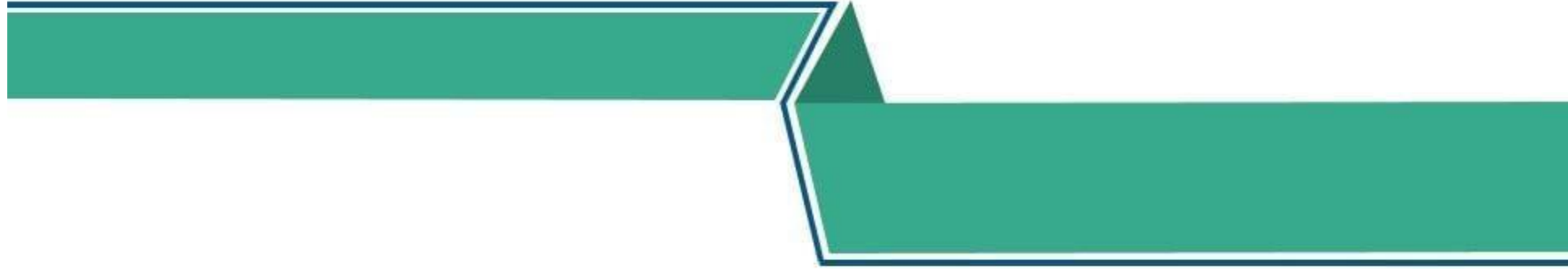
## **Lead-Oxide Glass (Lead Crystal)**

**Uses:** Used for decorative "crystal" glassware and specialized optical components.

## **Aluminosilicate Glass**

**Uses:** Primarily used for fiberglass manufacturing (for reinforced plastics in boats, fishing rods, etc.) and halogen bulb glass

“Thank You”



# **Nanomaterials**

**Prof. Dr. Mahir H. Majeed**

**Al-Furat Al\_Awsat Technical University**

**College of Polytechnics/Karbala**

# Introduction to Nanomaterials

**Definition:** Materials possessing at least one dimension less than 100 nanometers (nm).

exhibiting unique optical, electronic, magnetic, and mechanical properties different from their larger-scale counterparts due to their extremely small size and high surface area, finding applications in medicine, electronics, energy, and cosmetics.

# Why the Nanoscale is Unique

**Key Phenomena:** Introduce two main reasons for altered properties:

1. High Surface Area to Volume Ratio.
2. Quantum Effects (e.g., changes in optical/electrical properties).

# Classification of Nanomaterials (Dimensionality)

**Categorization:** Based on how many dimensions are confined to the nanoscale:

0D (Quantum dots, nanoparticles),

1D (Nanowires, Nanotubes),

2D (Thin Films, Graphene),

3D (Bulk nanostructured materials).

# Characterization of Nanostructures

**Visualization:** Techniques used to Image the structure and size.

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) are advanced imaging techniques that use electron beams in a vacuum to achieve high-resolution, high-magnification images of materials.

# Characterization of Nanostructures

**Analysis:** Techniques used to determine Composition and Properties.

Atomic Force Microscopy (AFM) and X-ray Diffraction (XRD) are powerful, complementary techniques for comprehensive material analysis. AFM provides high-resolution 3D, nanometer-scale imaging of surface topography, roughness, and mechanical properties, whereas XRD analyzes the bulk crystalline structure, phase identification, and crystallite size estimation.

# Applications: Nanotechnology in Electronics

Key applications include 3nm transistors for processors, high-density memory chips, flexible displays, and rapid-charging, high-capacity batteries.

These innovations significantly reduce power consumption and device size.

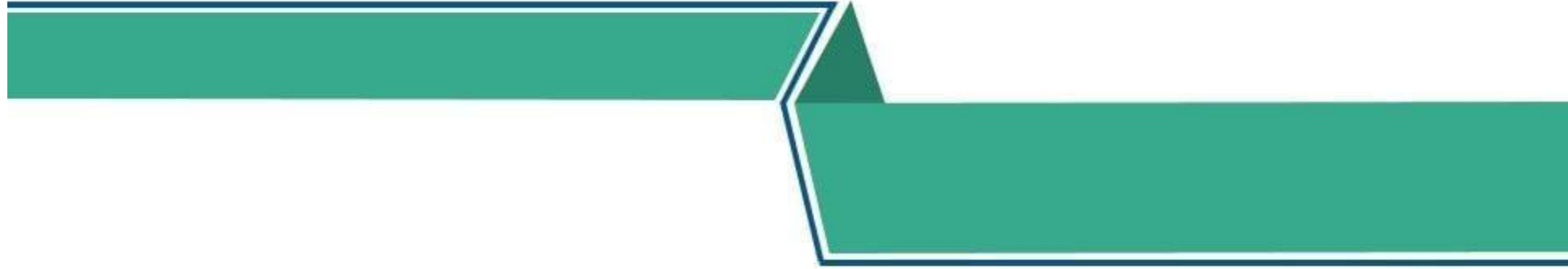
# Applications: Nanotechnology in Energy

Key applications include boosting solar cell efficiency via light trapping, enhancing battery capacity and charging speeds, developing high-strength wind turbine blades, creating efficient hydrogen-producing catalysts, and reducing industrial energy consumption through nano-coatings and lubricants.

# Applications: Nanotechnology in Medicine

Key applications include enhancing cancer treatments, improving imaging contrast, and developing smart nanomaterials to reduce side effects and enhance tissue regeneration.

“Thank You”



# **Composite Materials**

**Prof. Dr. Mahir H. Majeed**

**Al-Furat Al\_Awsat Technical University**

**College of Polytechnics/Karbala**

# Introduction to Composite Materials

**Definition:** A composite material is engineered from two or more distinct constituent phases (a Matrix and a Reinforcement), resulting in properties superior to the individual components.

# The Role of the Matrix and Reinforcement

**Matrix Phase:** The continuous phase (bears the load, holds the reinforcement, protects it).

**Reinforcing Phase:** Dispersed phase (provides the strength, stiffness).

# Classification by Matrix Material

## **Polymer Matrix Composites (PMCs):**

Uses polymer (e.g., epoxy, polyester) matrix.

**Characteristics:** Lightweight, corrosion-resistant, low cost.  
(e.g., Fiberglass, Carbon Fiber Reinforced Polymer/CFRP).

# Classification by Matrix Material

**Metal Matrix Composites (MMCs):** Uses metal matrix (e.g., Aluminum, Magnesium).

**Characteristics:** High temperature strength, higher stiffness than PMCs.

**Ceramic Matrix Composites (CMCs):** Uses ceramic matrix.

**Characteristics:** High toughness, high heat resistance.

# Classification by Reinforcing Phase

## Forms of Reinforcement:

1. Fibers (continuous/short, provides anisotropic strength).
2. Particles (isotropic strengthening).
3. Structural/Laminates (layers of different materials).

# Properties: Rule of Mixtures (Isostrain)

estimates composite properties (e.g., Young's modulus, density) assuming uniform strain across fibers and matrix, typically for loading parallel to fiber direction.

# Specific Properties and Anisotropy

**Specific Strength/Stiffness:** High performance per unit weight (key for aerospace/automotive).

**Anisotropy:** Properties depend strongly on the direction of the applied load relative to fiber orientation.

# Uses of Composite Materials

**Applications:** Aerospace (high specific strength/stiffness), Automotive (lightweighting), Sports Equipment (tennis rackets, fishing rods), and Construction (rebar alternatives).

“Thank You”

